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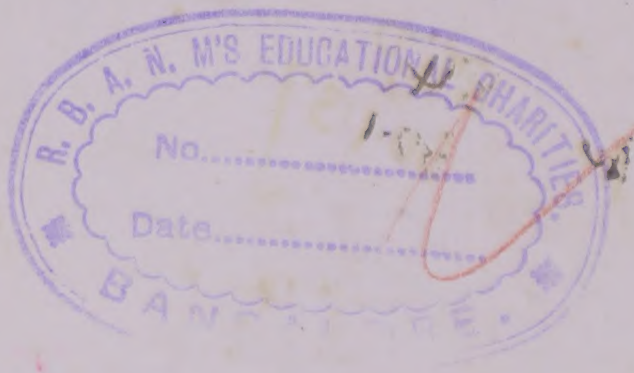

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THOMAS EDISON AND HIS PHONOGRAPH

The first words solemnly recited by this astonishing machine were, "Mary had a little lamb."

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SCIENCE THROUGH THE AGES

BY

MARION FLORENCE LANSING

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PREFACE

SCIENCE has made the world of to-day. It has created the tools of our modern life. But the science on which we depend for all our comforts and conveniences is no cold and remote force, acting on us impersonally from without. Science is human knowledge, gained slowly and painstakingly by men like ourselves and applied by them to the service of mankind.

This book introduces us to those pioneers in science who have created our modern world. In its stories we meet them at the high moments of their achievement. All down the ages there have been moments which made history. An invention which was hardly noted at the time, save by the few far-seeing men who projected it, stands to us for the beginning of a new epoch in the life of man.

Printing, self-running machinery, and talking across space, either with or without wires, are examples of those discoveries which have changed the world. Behind every such discovery there was a man or a group of men, bold, adventurous, clever, interesting. In these pages we meet those men, some familiar, and some unfamiliar, but all men to whom we owe a tremendous debt. And we meet them in the thrilling moment of their triumph.

We are all interested in ourselves, in our own world. Each group of stories, tracing some line of human thought, is brought to a focus in our present life. There is a happy arrangement of material by which we come in each group to our own interests. The early discovery of fire seems less remote when we realize that we are still living in an 'Age of Fire,' though there are those who predict that our children and our children's children may be living in the 'Age of Electricity' which is now dawning.

Early man invented the wheel; modern man has invented machinery to turn the wheels of the world, and has discovered how to use fuel, water-power, and electricity to keep that machinery going. Man has always wanted to fly. The petrol-driven engine has made it possible.

Time and space were baffling problems to the man of long ago. He was forced to live in a tiny, enclosed world of his own present existence. Writing, printing, photography, and the gramophone have given him one kind of control; clocks, telescopes, the telegraph, the telephone, wireless, the steam engine, the motor-car, and the aeroplane have won him other victories over time and space.

Boys and girls find themselves in this new, wonderful world. They are eager to continue its conquest. They are thrilled by its possibilities. It will help them in their understanding of the world to see how our modern civilization has been built up. To read of these pioneers and appreciate our debt to

them is like rendering thanks at table for the meal that is spread before us. It will make young people more proud of their human inheritance when they see how the battles of science have been fought all down the ages by men and women like ourselves. As these great moments in science flash on the screen of their consciousness they will catch a glimpse not only of the past and of the present, but of those great moments in which they may have a part when the next great discoveries will be made, the next great conquests won.

M. F. L.

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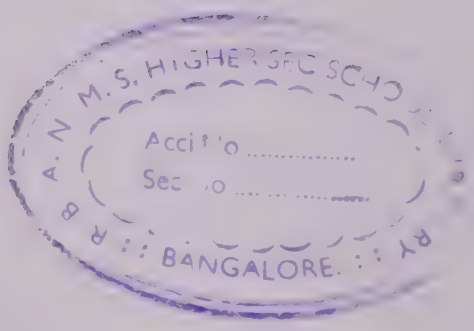
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SCIENCE THROUGH THE AGES

GREAT MOMENTS IN SCIENCE

LONG ages ago man found himself in this world. Although it was to be his home and the home of his children and his children's children to countless generations, he was a stranger here with everything to find out.

Every child who is born into the world is a stranger even in his own home. A baby finds out slowly about the room in which he stays, about the street in which he lives, about his father and mother and brothers and sisters. He finds out that he can walk, that he can talk. One day he goes to school into a new, bigger world than he has ever known before. Perhaps he travels and learns more and more about the world. Whatever he does, some one has always prepared the way for him, so that he can do it easily. When he grows older he does not have to learn how to build a house in order to have one to live in. If he wants to build a new one, the ways of building are all ready for his choice. He does not have to invent the telephone; the authorities will put a wire into his house. The newspaper and the wireless and the moving picture

bring to him news of the whole world. His books tell him of geography and history. The world is made ready for him.

It is pleasant for us who do find our lives made comfortable and easy and interesting to look back at the men and women who made our world so ready for us. This was done by men and women who lived on the earth before we came. Some of them lived very long ago, in the dim ages; of them we can gain knowledge only by the things they left behind them, the stone weapons, the cave drawings, and the altars to their gods. Others lived in the days of tradition, when the story of man's doings on the earth was passed from mouth to mouth, but never written down. Others lived in the early days of history; still others in the Middle Ages; some in the last few hundred years; while some are living now.

No bit of knowledge ever came except through its discovery by some human being. The earth on which the earliest man found himself was as rich in treasures as is the earth of to-day. But he had to find out its wealth for himself. It did not speak out its secrets. He must learn how to make fire and to melt iron out of the rock. He must find out how to tell time and how to steer his boats by a compass. Steam and electricity were waiting for him to find them out. Coal and oil to run his machines lay buried in the earth. With them he could work wonders; but he must discover them and their uses.

It is because man has been so clever in this business of finding out that he is to-day not a stranger, but a master, a conqueror in his world. He has travelled during the centuries a long, uphill road. It has become in his progress along it a royal road to victory.

As there had always to be some man, eager, adventurous, and industrious, to add every bit of knowledge to the human store of information and of skill, so there was always a moment in that man's lifetime when he first caught sight of the new fact or the new way of doing something which would make him and his neighbours wiser or more comfortable or richer or happier. Those are the moments of which our stories are to tell.

Science is knowledge, human knowledge. Human knowledge has grown by leaps and bounds. The great moments in science stand out through the ages as man's moments of insight and victory. In them man, a creature of mind and spirit, is shown in his conquest of a world of matter.

THE AGE OF FIRE

The Secret of Fire-making: The Rock that Melted—Iron

FIRE is man's most precious possession. Think what would happen if all the fires in the world went out and no one knew how to rekindle them! Our homes would be cold; our food would remain uncooked; our trains and our steamboats would stop; our factories would cease to run. Most of the things we eat and drink and wear and handle could no longer be made. We live in what may well be called 'The Age of Fire.'

The Age of Fire began many, many thousands of years ago. There is no tribe on the face of the earth that has not a story of how fire first came into man's possession. Because no other living creature can make a fire, and because the ability to make one sets man far above the animals, every story tells how fire came to man from the gods. The Greeks tell how Prometheus went up into Heaven, lighted his torch at the chariot of the sun, and, stealing fire, brought it down to earth. The gods had never meant that man should have fire, for they knew that if he did he would become as one of them. With it he could win from the earth her secrets and make use of her treasures. No! the gods never

meant that man should win this miracle-making power to create fire.

No one really knows how man *did* find out the secret of fire-making. Perhaps he saw the lightning come from Heaven and set the dry forests on fire. Perhaps some man, bolder than his fellows, kept the fire that came from Heaven when he found it burning in the woods, and tended his firebrands and fed them with dry wood and warmed himself in their heat. If he did, we may be sure that he was looked upon by his tribe as one who was to be feared and reverenced because he knew the secrets of the gods. In every tribe there were the keepers of the sacred fire. They watched by the fire day and night and fed and tended it, lest it should go out and this precious gift of the gods be lost and man perish in the cold.

For many hundreds of years after man knew how to tend and keep fire he probably did not know how to make it. He could only seek it out where the gods of the lightning or the forest had lighted it, and carry it to his cave and cherish it.

Then one day, either in rubbing a piece of pointed wood against a hard slab to sharpen the point, or in striking two flints together, man made a fire for himself. That was the greatest moment in the life of early man. With this power in his hand he had the key which should unlock for him the treasure-houses of the earth on which he dwelt.

Because we do not know the true story of the moment when man first found out the secret of

fire-making, since it is so far back in the days before history or tradition, let us re-tell the story as the Polynesians tell it of the way a bold and adventurous man won the secret of fire-sticks and their use from the Fire-god Maui.

THE SECRET OF FIRE-MAKING

(*As it is told in islands of the Pacific Ocean*)

Long, long ago, when man had only recently come to dwell on the earth, no mortal knew the secret of how to make fire. Only the gods of the underworld knew that, and they guarded it closely lest man should learn it and be as wise as they. Fire dwells in the underworld, as every one knows who sees its smoke coming out of the top of a mountain. But the way to the underworld was hard to find, and the watchers at its gates were many.

Once upon a time there was a youth called Maui, who dwelt in the upper world, on the earth where mortals live. He was a mortal, but his father and mother lived in the underworld and came and went on the errands of the gods.

When Maui's mother, Buaratanga, came to see him she would never eat with him. Always she took her basket and went off by herself to eat the food which she had brought with her from the underworld. One day while she slept Maui looked into her basket and took some of the food which was there and tasted it. It was better than anything he

had ever eaten. Although it was like his food, still something had been done to it that made it better.

Maui had heard of fire, and of how the gods cooked their food over the fires they made. If fire made food as good as this he must have it. He made up his mind to follow his mother secretly when she returned, and to brave the dangers of the underworld in order to get this precious gift.

Maui followed behind his mother and slipped past the watchers of the first gates. At some of the inner gates he had to wait a long time until the guards were changed, so that he might get by while they were talking. But after many adventures he came to his mother's house and told her that he would not return to the upper world until he had learned the secret of fire-making.

"Ah! but I do not know it myself," said his mother. "None but the Fire-god knows that secret, and he will not tell it. When I want a new fire I go to your father Bu, and he goes to the Fire-god and asks him to let him have a bit of burning wood."

"Then I must go to the Fire-god and learn the secret from him," said Maui.

Buaratanga did her best to keep her son away from the Fire-god, for she feared lest some harm should befall this mortal son of hers in the underworld. But Maui insisted that he would go. He asked where the Fire-god lived, and his mother pointed out the way and told him the place was called "The House of the Banana-trees."

FIRE WITHOUT MATCHES
Making fire to-day as Maui did long ago.

As Maui started off she said to him, "Beware, Maui! Be very careful, for the Fire-god is very powerful and he may be very angry."

Maui went to the Fire-god's house, which he knew at once by the smoke which was rising from its roof.

The Fire-god was busy cooking his food, but he stopped to ask Maui what he wanted.

"A firebrand," replied Maui.

"No mortal can have a firebrand," replied the Fire-god, and went on with his cooking.

Maui told him how mortals needed fire, and how he had come all the long way to get it for them.

"Mortals know too much already. If they had fire they would think they were gods," replied the Fire-god, and turned his back on him.

Maui turned away sorrowful, for he saw that the Fire-god would never teach him his secret. But he determined to stay concealed near the house and see if he could not find it out for himself. Although he had asked for a firebrand, as his mother told him that his father did, he saw as he watched the fire that a firebrand would not help him, for he could never keep it burning during the long journey to the upper world.

Maui hid himself in a banana-tree and waited, watching the Fire-god as he fed his fire. Then, when he was weary and hungry and almost ready to give up and go to his mother's house, fortune favoured him. Down through the hole in the mountain through which the Fire-god sent up the

smoke of his fire into the upper world (where all men may see it to this very day) there came a downpour of rain. Now, the Fire-god's fire was right under the hole, and so quick was the coming of the water that he did not even have a chance to snatch a firebrand. Before he had time to turn round his fire was gone.

At first the Fire-god was too angry to do anything but curse the rain which had put out his fire before his food was half cooked. Then he looked about him to make sure that no one was in sight, but he did not see Maui away up in the tree over his head, looking down into the house. Then he went into an inner room and shut the door and picked up from a corner a heap of coconut fibre which lay there. From another corner he took a dozen sticks of banana wood. In the centre of the room lay a small block of hard wood with a hollow in the middle.

While Maui watched eagerly from above the Fire-god took the light banana stick and began to twirl it very fast, keeping its point pressed down hard into the hollow of the block of wood. As he twirled he sang :

"Give, oh, give me thy hidden fire,
Thou banana-tree!
Kindle a fire for me
From these thy splinters,
Thou banana-tree!"

As Maui watched he saw a light smoke begin to

come where the twirling stick rubbed in the hollow. Then the smoke came faster. When the smoke was beginning to rise the Fire-god threw coconut fibres on it, and soon, to Maui's surprise, there was a bright fire burning.

Maui lost no time in hurrying back to the upper world. There he took coconut fibres and banana sticks and a block of hard wood and went to work with them, to see if he could make fire. It took him a long time to get the trick of it, for fire-making is not easy, as you know if you have tried it; but he learned from many trials just how to hold the dry banana stick and twirl it, and just how hard he must press it into the other wood.

When Maui had proved that fire lived in the banana-tree, and that anyone could get it with fire-sticks, he went and told his secret to the heads of his tribe. They came by stealth and watched him make a fire. While some of them feared that the anger of the gods would come on them because they had learned this secret which was not for mortals, the bolder of them rejoiced at this power that had been put into their hands.

So after man learned that the fire dwelt in wood and could be called out at will, he could always make a fire and cook food for himself and warm himself. It was a great day for man when he learned the secret of fire-making.

THE ROCK THAT MELTED—IRON

In the olden days, while the world was still young, we are told that there dwelt in the valley east of Eden a young man called Tubal-cain. He was the grandson of that Methuselah who lived longer on the earth than any other man has ever lived.

Tubal-cain went out on the mountains to be a hunter for his tribe, for he was strong and mighty of stature, so that he could throw a stone-tipped spear with a long, swift swing at the wild beast whose life he sought. Also he was keen of sight and quick of movement, so that he could spy a creature lurking in the forest and follow swiftly in pursuit as it fled.

Tubal-cain knew the secret of fire and of fire-making. This secret had not been known for many generations in his tribe. A man from the North had taught it to their wise men. He and his tribe had caught the fire which came in lightning from Heaven and kept it until at last they learned to make it for themselves by calling the fire-spirit out from the wood in which it dwelt. Tubal-cain played often with the magic of fire. On many a cold night he kept himself warm by coaxing the red flame out of the wood and feeding it with dry brush which he had gathered in the day. He found that prowling beasts were afraid of this spirit and slunk away and did not disturb his slumbers while it stood guard over him.

One very cold day Tubal-cain gathered a huge pile

of brushwood and dry logs and set the red spirit to eating it, for he was cold. He had been out in the high mountains all day following a giant tiger. The wind was fierce and cold from the north, and he was chilled to the bone. So he sat long by the fire, and as he gazed into its depths he saw a sight stranger than any he had ever seen in all his life. A stone which lay in the centre of the flame turned red-hot as it lay there, and all of a sudden it began to melt. As it got hotter and hotter there came out of the fire a stream of melting rock like muddy water that was trying to run away. It lay in a long coil as it ran, turning dark like a black serpent as it escaped from the heat of the fire which had driven this strange substance out of the stone. Tubal-cain did not know it, but that was the first time any man on earth had ever seen iron, for this stream as of liquid fire which ran away and cooled was a stream of that precious metal which had been hidden in the ore.

For many, many weeks and months after he saw the red stream flow out of the rock he picked up rocks from the mountain-side and brought them to his fire and tried them to see if they would melt. Some gave out this stream which was iron; others had bright shining drops which were of the softer metal that we know as copper. Every bit of stone that looked like those which he had seen first he tested; and he watched as they cooled to see in what shape they fell.

One day he tried to shape some of the hot metal

as it cooled, and it yielded and let him press and pound it into a point like that of his stone spear. The next time a wild beast came near the cave where he lived on the mountain he threw this new spear at him. It struck him on the forehead and killed him instantly. That was the first metal weapon that he had made. It suggested to Tubal-cain that he might make other weapons of these new substances which could be hammered to an edge sharper than that of the stones or flints on the shaping of which he had spent so many weary hours.

To the other hunters who came sometimes to his camp in the hills and to the dwellers in the valley he said nothing of his secret. Yet they marvelled at his great prowess and skill as a hunter, for he brought in more game than any other two men of those set on the mountain-side to bring in meat for the valley folk and to protect them from the ravages of the wild beasts.

But to his grandfather Methuselah he told his strange discovery, showing him all the kinds of spearheads and pointed arrows and blunt tools which he had made and shaped by heating and pouring into holes and cracks in the rock the metal as it came hot from the fire and leaving it until it cooled and hardened and could be hammered and beaten.

Methuselah was nearing the end of his life when Tubal came to him. But his wisdom increased with his length of days, and he was as keen and quick in thought as his youngest grandson. He took the

strange, heavy pieces of dark iron which Tubal-cain brought him, and the shining pieces of copper, and weighed them in his hand and tried and tested them in every way. He told Tubal that this was a wonderful secret which he had wrested from the earth, and that he must study these rocks and work with them and learn all that he could, so that he should be ready to share his knowledge with his brothers and kinsfolk and pass it on to all the world.

So Tubal-cain went back to the mountain and built for himself a fireplace or furnace in which he could imprison the spirit of fire and keep it as his servant. He set all the hunters to bring him stones of the kind that melted. He learned to make clay moulds into which he could pour the hot metals, and to let the air in below his fire-pot so that he had a rude bellows. There he made weapons for all the hunters and for the men set to guard the valley folk.

Men came from far and near to learn from Tubal-cain the art of working with metals, and he taught them gladly all the secrets he knew and the arts he learned from day to day. Whatever he learned was at the service of all men, for how else could men live and prosper on the earth save as they shared, for the good of all, the finds which any one man or any one tribe might make? He learned how to handle iron skilfully; and he was not satisfied to make only weapons for the fight. He shaped a heavy curved point by which a man could dig into the soft earth before he dropped seeds into it, and a long blade

such as we call a plough, so that he could lay lines of seeds straight in furrows. Many were the tools he made, and he was known far beyond his own valley or the valleys that lay just beyond his hills. Even across the rivers and to the edge of the great sea, so far was known the name of Tubal-cain as the forger of every weapon that cut with an edge or drove with a point, and the teacher of every man who sought to work in copper or iron or any other substance that flowed from the rock; and so it is written in the ancient books, as you may see for yourselves.

So the Age of Fire became also the Age of Metal, and in that age we live to this day. However it may have been that man first learned to make fire, we know well that he *did* learn to make it long before the days of written history. And when he learned also the secret of metal as it is hidden in the earth, and of how to handle and shape it with the aid of fire, then he was well started on the road to civilization which we shall watch him travel down the long centuries to this very day.

A FOOD CYCLE

Five Finds—On the Road from Clay to China: The Powdered Wig: A Tribute to the Tin Can

FOOD is a daily need of man. The cave-man had to have food to keep himself alive just as we of to-day need a constant supply of food to keep ourselves alive. Many of the most interesting stories of human life centre about this great question of food, with which all mankind is so busily engaged all the time. Some of these stories are connected with trade and commerce, others with exploration, with industry, and with the history of separate peoples.

At first man had to be always 'on the move' to find his food. He ate berries, fruits, herbs, grains, and the roots of plants, and then went on to fresh fields where he would find more. He stayed for a time in one hunting-ground, then sought another.

Then came the wonderful day when he learned that if he planted a seed he would win a harvest. All over the world in those long-ago days there must have been among each of the peoples some one who watched the march of the months as the moon came and went, and who tried for the first time the experiment of putting in the ground one of the seeds used for food to see if it would grow and bring forth a

harvest. A Malay chief tells how in his tribe the people used to live on the fruits of the jungle. At first they ate the fruits in small shelters which were set up near the spot where it was gathered. But it was noticed that many fruit-trees sprang up near these shelters. So they decided to carry the fruit a little distance before eating it. Every year, after they found out that fruit-trees came up where the stones or seeds of fruit were dropped, they carried the seeds farther away and dropped them in different places, until at last they had orchards all over the region where they lived.

When the secret of seed-time and harvest was discovered, then man could stop wandering up and down the earth and stay in one place and cultivate the land for food. Sooner or later most of the tribes found this out and settled down.

Man's food needs are the occasion for his creation of pottery—of vessels to hold water, of vessels for cooking, of vessels for keeping food from meal to meal, and finally of vessels for serving food. With the interest in the manner of serving food comes the change from heavy earthenware to thin, translucent china. Families sit about a common table and eat together, first out of a common dish, and then with individual dishes.

Meanwhile there has been progress in another direction which is connected with the world's food-supply. Man has compassed the earth with his railways and ships. He can carry food from north to

south and from east to west around the whole globe. But food, to be carried over long distances or kept for long periods, must have more than a hand-to-mouth term of preservation. It must be kept sweet and sound and fresh. The sealed tin can meets that need. By its means the food cycle is completed.

At first man had to move frequently to find food; hence the great migrations. Then he learned to cultivate food at home; hence the great separate civilizations. Now he can carry food anywhere; hence our modern freedom of movement. The stories swing us round the whole circle. At first he had to move; then he could stay at home; now he can either move and take a variety of foods with him, or sit at home and have the food of all the world brought to his own table. In the stories of the Malay chief and his seeds, of the potter's art and its effect on cooking and serving food, of the alchemist and his discovery, and of the French scientist who won a prize, we see how these things came about.

FIVE FINDS—ON THE ROAD FROM CLAY TO CHINA

There are some stories which might be told of every tribe on the face of the earth during those early days when man was learning about the wonderful world in which he lived and the treasures which

awaited discovery. One such set of stories is of the earth beneath his feet.

The earliest cave man must have noticed that in some places the earth was dark and rich and fertile, in others rocky, and in others sandy. Somewhere in each district where a tribe of men lived—perhaps on the bank of a river, perhaps in the dry bed of a stream or in a hollow near their dwellings—men took note of a sticky kind of earth in which foot-prints left a mark that hardened in the sun. It may have been a man or a woman, or a child making mud pies after the immemorial fashion of children at play, who first took wet clay and patted it into a flat disc or a chunk with a hollow in it, and then came back to find that the disc or the hollow lump was no longer soft and sticky, but had hardened into the shape which it had been given. Whatever the way in which this discovery was made, it came about that every tribe of which we have any knowledge made in early times its own rude vessels and solid bricks out of clay. The potter's art, which is the art of shaping clay into useful and beautiful objects, is the oldest and most widespread of all the arts.

The story of man's increasing knowledge of this wonder-earth beneath his feet and of his increasing skill in the use of it lies in the story of five lucky finds, five discoveries which were made at some time in the history of each people by some member of the tribe. These finds may have been made in quick

succession in some tribes; in others they would be made at intervals of one hundred, five hundred, or even a thousand years. But each discovery had to be made afresh in each tribe by some clever and industrious person before it was put into common practise by all the workers in clay.

The first find would be that a certain kind of earth was really a clay, which was very soft when it was moist and very hard when it was dry, and that a mark made in it when it was soft would stay in it as it hardened in drying.

The second find would be that a dish could be made by laying strips of this clay one upon another, and leaving it in the sun to harden. The making of a dish was really a great moment in the life of a people, though they would not know it at first as such. A dish that would hold water and keep its shape when swung over a fire or buried in a fire-pit made real cooking possible. No longer was it necessary to scorch meat over a hot fire by hanging it on sticks, or dry it by burying it in an oven. No longer was it needful to pound grain to a pulp so that it could be swallowed. The magic of fire could be turned to good use in the preparation of food, when once there was a fireproof dish or pot to hold the food.

The third find would probably be that if this clay were mixed with sand or some other substance it would harden more firmly. While this would be convenient in the making of dishes, it would be even

more important in the making of bricks for house-building. Do you remember in the story of Moses how the people of Israel complained that they could not make bricks without straw? Straw served the same purpose as sand in giving firmness to the clay brick. In Egypt, in Mexico, in the southern parts of the United States, everywhere in the tropics where clay beds are to be found, there are huts or 'adobes' made of sun-dried bricks. The first bricks are worth our notice as an important stage in man's life, since they made possible so great a gain in the kind of house in which he dwelt.

After fire came into common use it happened on some occasion that a roughly shaped dish or a crude brick was left near a fire. That dish or brick was found next day to be hardened as no sun-dried piece of clay had ever hardened. It was as firm and solid as a piece of rock. No water would soak through it; no pressure crumbled it. Fire-baked clay was *the fourth great find* in the history of pottery. It was a long time before people learned fully the arts of firing their dishes. They built kilns, which were ovens shaped often like beehives, into which they could put a fire which would burn slowly and steadily for hours or days. Then they experimented as to just how much heat was best for each kind of mixture, and how long each variety of clay should stay in the kiln. But this secret of fire-baked clay is at the basis of all pottery and brick-making—of all china dishes, all beautiful vases, all brick and

A Potter at Work in Upper Egypt To-day

From a photograph by Winifred S. Blackman

cement buildings, of thousands upon thousands of objects which make up our modern civilization.

The fifth find belongs to a much later date, long after man had learnt to crave for beauty as well as for usefulness in the objects wrought by his hands. Even in the earliest ages potters had tried, in their rough way, to ornament their clay pots, though it were only with a line of thumb-nail marks along the rim. The Egyptians and the Babylonians and the Medes coated their jars and bricks and images with a brightly coloured glaze made from the oxides of antimony, copper, and tin. The Greeks used a sort of hard varnish upon the surface of their beautiful black-and-red painted vases. But the art of making porcelain, translucent, shining, delicate, was first discovered by none of these peoples. Chinese potters had begun to experiment with firing clay in kilns at a time when their unknown fellow-craftsmen in other countries were still drying their earthenware vessels in the sun. The use of glaze was frequent in China two hundred years before the Christian era, and by the seventh century A.D. the Chinese had learnt how, by combining a special sort of clay called *kaolin* with a siliceous stone known as *petuntse*, a much finer substance might be produced. Kaolin bears the name of the mountain (Kao lin, lofty ridge) whence the first supplies of this wonderful clay were obtained. It is infusible, that is to say, it will not melt even when subjected to great heat, and its purpose is, in the Chinese phrase, to ' form the bones of the ware.'

Petuntse, which resembles Cornish granite, *is* fusible at a high temperature, and dissolves into transparent glass. It was by skilfully blending these two materials that the Chinese potters were able to make that beautiful ware which we call 'china' to this day. Not for nearly a thousand years was their secret penetrated by investigators working and experimenting in the West. And now comes the story of the angry alchemist and the heavy wig.

Before we re-tell this last story of china we must glance at the origin of the kindred art of glass-making, as told by Pliny, a Roman writer who lived in the first century A.D. This is the story of a sailor's find.

A Roman merchant ship was making its way across the Mediterranean Sea with a cargo of natron (native carbonate of soda), which the ancients used for washing and bleaching. As they sailed along some adverse wind drove them ashore on a beach of fine white sand at the mouth of a river in Syria. The crew lighted a fire on the sand to cook their food and happened, in the absence of rocks, to use lumps of natron from the cargo to prop up their kettle. What was their surprise to find a stream of transparent molten glass running down from their camp fire to the water! The sailors had landed on a beach of sand powdered by wind and weather from some one of those minerals which are used in making glass. The heat of the fire and the addition of natron, making a mixture that melted at a low heat, had given the surprising result. We may well be-

lieve that the sailors took home some of that sand as an addition to their cargo.

This is only one story of glass-making from many which might be told. It shows how in one part of the world and another the properties of different substances were being found out by one group of people here and one group there. If they had been in touch with one another, as all nations are to-day, and if they had trusted one another with their secrets, civilization might have been much more widely different and have come many hundred years earlier. But those were the days before the art of printing made the exchange of knowledge a simple matter, days of separate peoples shut off from one another by oceans crossed only by small sailing vessels, when deserts and mountains were unspanned by railways. They were the days when each people feared every other. A great discovery in science might be made in one country, and might be held with the strictest secrecy from every other. So it was with the art of making china.

THE POWDERED WIG

One morning in the year 1708 there was trouble in the royal palace in Saxony. The Elector, Augustus the Strong as they called him, was angry, and when Augustus was angry he did not keep it to himself. He let his ill temper be felt by all with whom he came in touch, from the serving-man who brought

in his wooden trencher to the groom who held the stirrup of his horse. Nothing in the household was too small to escape the Elector's vigilance, no slip too unimportant to incur his displeasure when he was in such a mood.

"When did it begin?" whispered Otto the serving-man to Ulrich the esquire-in-waiting, as Augustus threw down his trencher and strode angrily from the dining hall declaring that the bounteous repast of boar's meat, of which he had partaken heartily and with apparent relish, was not fit for the pigs in the courtyard. "All was well when he came back from Poland yester-eve."

"Mayhap it is some matter of State," said Ulrich "They say he will be King of Poland if matters go on there among the nobles as they are going now."

"He went into the secret workshop this morning," volunteered a page who was listening to their talk.

"Ah! is that it?" said Ulrich. "There is magic in that place. A visit thither bodes no good."

"What are they doing there?" asked the page curiously. "I see queer-shaped flasks and heavy jars being carried in, and none may ever ask what comes out, or so much as peer though the guarded doors to see what is going on there."

"Speak not so loud, my lad," said Ulrich sharply, "and cease to hang round the drawbridge that leads to that tower if you value your place here. Better to keep eyes and ears closed where the powers of darkness are at work."

"Nay, speak not so," said Otto, smiling at the frightened page. "What surer way to drive any lad of spirit straight to the devil himself than to tell him to go about with eyes and ears closed lest he see him? Herr Böttger is no prince of darkness to cast a spell on thee, boy. But his business is his own and that of Duke Augustus, and they do not desire curious or prying mischief-makers to be putting their noses into it."

"But they say Herr Böttger is a wizard," burst forth the lad in all excitement, "and that when he was an apothecary's apprentice in Berlin he studied under no less a master than the Greek monk Lascaris himself, the magician!"

"There, Otto, you see what you get," said Ulrich. "The boy's ears have been filled with tales already, and he knows full well that the wicked arts of alchemy are being practised in yon tower. Talk about it if you will, and if you dare; but as for me I believe that the very walls have ears where the powers of evil are concerned." And Ulrich strode off in disgust.

"But, Otto, kind, good Otto," cried the boy, "tell me more of this, for you know I am new to the castle, and you are so wise and have been here so long."

"Aye, lad, I was here when young Böttger came as a lad of sixteen to place himself under the protection of our noble Elector Augustus."

"But why did he flee, and whence came he?" questioned the lad.

"He fled from Berlin, where he was indeed, as you say, an apothecary's apprentice, but had happened on some secret in his study of alchemy with the great master Lascaris which put them all in danger. Some said they were on the point of finding the philosopher's stone itself, and that the greedy duke under whose patronage they worked sought to imprison them all, lest they should reveal the secret, when they found it, to another rather than to him."

"The philosopher's stone," whispered the page, looking at Otto with eyes wide open with wonder; "the stone which will turn all it touches into gold?"

"Aye, the very same," said Otto, "and right glad was our lord Augustus to harbour a brilliant young alchemist who might unlock that secret any day."

"And has he found it?"

"Nay, methinks that is why our lord Augustus comes forth from the workshop angry. The Elector has done what he could. Fearing that no lad of sixteen years could master any such secret alone, he brought hither the wise Herr Walther von Tschirnhaus, a master in alchemy and all the lore of books, and together they worked for many years and brought out nothing from their workshop to show for their toil but some red clay dishes. At least, that was all that ever I saw. Pretty enough they were, if you cared for colour in your dishes, and the master was so proud of them that he sent them down to the fair at Leipzig, where they made a great stir, I am told. But for a man who is seeking a magic

that will turn all the baser metals into gold to bring forth nothing better than red dishes, when all the world knows that food is food whether it be eaten off wooden trenchers or common earthenware bowls or fancy red ones—no wonder the master is angry, I say."

"But where is this Herr Walther? I have never seen him," said the lad.

"Nay, he died these two months past," replied Otto, "and that is why it bodes ill for Herr Böttger if he find not some secret soon, as our master's black looks on this very day would seem to show. But come, lad, we must be about our duties and not stand gossiping like two old wives. Yet I like not to have thee frightened by friend Ulrich, who thinks, as do many in the castle, that the very prince of devils dwells in the tower and comes forth at the call of our neighbour Böttger."

Otto went his way, but the troubles of that morning were not over. Presently the door burst open and in rushed the master alchemist himself, Herr Böttger, who so rarely came out from his tower. Like the Elector an hour earlier, he was in a state of great excitement. He strode along waving the powdered wig which usually covered and gave dignity to his long, narrow head, and calling loudly for the valet who had powdered it.

"Could I take it to him, sir, if it is not right?" asked the page timidly.

"Not right?" shouted Böttger, "who said it was

not right? Where is the fellow who powdered it? Where is the powder? Where did he get it? I must have some more at once!"

And then, with the precious wig clutched in his hand, and his own locks in wild confusion, he rushed out of the hall.

"Truly I know not whether it is Ulrich or Otto that is right," the lad murmured, crossing himself as he spoke. "Herr Böttger looked the madman at this moment, as if the powers of darkness were pursuing him!"

We who are permitted to cross the drawbridge and enter the workshop in the tower where all this mystery began will soon find out that it is not because Herr Böttger did not like the way his wig was powdered that he was searching madly for his valet, but because he liked it uncommonly well. At the moment he wanted more than he had wanted anything for many a day some of the precious powder which he had found so unexpectedly in his wig.

Otto's story was right as far as it went, but by his own admission he had never crossed that drawbridge or known except by hearsay of what went on there. Like all alchemists Böttger and his associate Walther von Tschirnhaus had sought the secret of the philosopher's stone which should turn all metals into gold. But the Elector Augustus was more than a seeker after such a will-o'-the-wisp as that had proved to be. He was a practical man, as well as

a man of culture. Living as he did in the period of exploration and travel, he was keenly interested in all that other far-off nations were doing in the practice of the arts. In his early life he had collected arms and armour from all the countries of Europe and the lands that bordered the Mediterranean Sea. His next enthusiasm had been for silverware and jewellery, of which he had a rare and beautiful collection. Both of these collections, or such of them as remain, may be seen to this day in the museums of Saxony, where they are among the chief treasures exhibited. About the time when Böttger fled to him for protection and patronage, he had become greatly interested in the beautiful chinaware that was being brought by Dutch traders to Europe from the distant lands of China and Japan.

In Europe in the year 1700 there was salt-glazed stoneware for common use, and there was also a pottery glazed with lead. For the tables of the rich there was a kind of ware which was coated with an enamel. But all these kinds of pottery were like the electroplate of to-day. They were of one ware underneath with a coating of another. If the coating wore off, as it did with time and wear, the paste or earthenware beneath was common and porous. A stain of greasy water that went through the enamel at a place where it was chipped would spread round the hole and make an ugly spot.

The sets of dishes from China were clear and

beautiful. One could hold them up to the light and see that they were all of one material. They were thin and delicate, too. To a collector like Augustus they were a treasure to be bought at almost any price and appreciated for their beauty and fine workmanship. So fond of them did he become that he once turned over to the King of Prussia a company of his own soldiers, tall, well-trained Saxon dragoons, in exchange for one hundred pieces of rare Oriental pottery which that King had collected.

At first Augustus was satisfied to collect pottery from abroad. But by the time Böttger was established in his laboratory at the castle, there had come to the Elector the ambition to have pottery like this made under his own patronage. Why should the Chinese be able to make this beautiful ware, while Europeans with their skilled artisans and alchemists produced only glazed or enamelled earthenware? He put the problem to his young alchemist, and the result had been in 1707 the red porcelain shown at the Leipzig fair, made from a clay which Von Tschirnhaus had found in the neighbourhood of Dresden, a beautiful ware which was far in advance of anything that had been produced in Germany up to that time, but still not the translucent white pottery of China. Böttger had grown weary of his royal master's demands after he had succeeded in making this red porcelain and had sought to escape from Saxony and set up a factory under some less exacting patron. But

Augustus had brought him to the old castle where he himself dwelt and placed him in this tower where, though Otto and Ulrich knew it not, he was practically held prisoner until he should bring forth a pottery like the wonderful white ware from China. Such was the true state of affairs up to the day of our story.

Although they had sought far and wide, Böttger and his patron had been unable to find any clay from which a white porcelain could be produced. On this particular morning the alchemist had put on his wig absent-mindedly and gone about his work. But his head felt heavy and dull, and at last it occurred to him that his wig was heavier than usual. He took it off to see what the trouble was and found that a white mineral the like of which he had never seen had been substituted for the usual starch.

When Böttger had hunted down his valet and demanded the secret of the powder, the frightened servant told him that he had meant no harm in the change. A man Schnorr had found a bed of this clay-powder near the village of Aue and had sold it, claiming that it would give a purer white to the wigs on which it was powdered and would last longer than the usual starch. Böttger, as you will have guessed, had tested the powder, and concluded that it was in all probability the long-sought kaolin of which travellers in China had brought back reports.

Following that morning's discovery Böttger went to visit the clay bed and purchased it for the Elector.

From its clay he was able to make as perfect a paste as that produced by the Chinese. In 1710 there were on view at the Leipzig fair, not only dishes of the red porcelain, but a few specimens of beautiful white porcelain " made by Johann Friedrich Böttger, under the patronage of Augustus the First, Elector of Saxony."

The next year the Meissen porcelain works were set up at Meissen Castle near Dresden, and the making of the world-famous Dresden china was begun. Poor Böttger's discovery brought him little luck. The Elector, who was by this time also King of Poland, was as secretive about his china-making as he had been about his gold, or as the Chinese were with their wares. Workmen engaged in the work were imprisoned in the castle and made to swear that they would keep the secrets of the craft " till the tomb should seal them." Böttger himself was virtually a prisoner while he supervised the factory and pursued, along with his studies in china-making, the secret of gold-making. By 1716 he had perfected the art of porcelain, so that his dishes were technically as perfect as those of the Chinese. In 1719 he died at the age of thirty-four. Lumps of his alchemist's gold, the fruit of his most earnest endeavours, are shown to-day in the museums of Dresden beside his chinaware. One wonders whether he had any realization of the importance to the whole Western world of his discovery of the latter.

The eighteenth century was transformed by these

discoveries. Once for all Böttger had solved the great problem of the making of a hard, white, translucent porcelain. His china stands to-day as the type from which all our china is produced. Kaolin (or china clay) beds were found in Limoges, France, through a woman's accidental discovery of a white powder clinging to the roots of plants pulled up in her garden; and the manufacture of china was begun there, which continues to this day. From the setting up of these two centres date the changes which have come in the daily service of food, as the old wooden trenchers and earthenware or stone platters, into which all dipped their fingers for food, were replaced by individual china sets.

And the beginning of it all was with an alchemist who found his wig unusually heavy one morning.

A TRIBUTE TO THE TIN CAN

A humble servant of mankind is the tin can. We destroy it in the opening and cast it aside without a look of respect or a thought of gratitude for its services. Yet the great Napoleon was so eager for an article which should perform in some slight measure the services it renders that he and the French Government offered in the year 1800 or thereabouts a prize of 12,000 francs to the man who should invent a successful container for preserving foods in war-time.

The succession of seed-time and harvest, which our earliest forefathers learned to recognize, is one of the great blessings of man; but it also imposes on him certain duties and cares. A man living in the temperate zones cannot have, with his best efforts at agriculture, a perpetual table spread before him. He must have daily bread; but the fruits and grains and other products of the earth come only at certain seasons. As the squirrel stores away nuts in the hollow of a tree, in anticipation of the time when there will be no food at hand, so man must preserve the products of the season of plenty for his use in the lean seasons of the year.

The oldest method of food preservation is drying. The first American settlers found the Indians practising the age-long customs of drying corn, fish, fruit, and meat to keep them from decay. Another means of keeping food is to chill it, a method which can be practised only in climates where food can be kept cold in water, by ice, or in shafts sunk deep in the earth. The opposite method of food preservation is by heat. When the earliest cooks found that cooked meat kept longer than the same meat when left raw, they had made the first of the chain of discoveries which leads us to the omnipresent tin can of to-day.

The secret of the success of the tin can is that the food in it is tightly sealed. The advantage of sealing food is not a recent discovery. On the island of Crete, in the Mediterranean Sea, there are

ruins of an ancient palace, dating from 1500 to 2000 B.C., in the cool underground galleries of which are found great earthenware jars where food was stored and sealed from the air. But for skill and success in the canning and sealing of food, so that it will keep for long periods, we must wait till the period of the Napoleonic wars in France when even the Government—and a government is always slow to spend money on inventions of uncertain public benefit—thought it worth while to offer a prize for a successful method of preserving foodstuffs by canning.

Twelve thousand francs was a large sum in those days of the turn of the century. The confectioners and brewers and distillers went to work with all haste and diligence to see if they could win it. The prize went after a dozen or fifteen years to François Appert, a confectioner, who had worked all his life on this problem.

Perhaps it was the rumour of Appert's labours which set Napoleon and his councillors thinking about the value of a scheme whereby food could be successfully preserved. At any rate, the prize was offered, and Appert persevered with his patient work until, in the year 1810, he could offer the proof of his success and gain the reward. Even then he sank all the money in his invention, still testing and experimenting for better ways, until, despite the twelve thousand francs which had seemed so large a sum when it was offered, he died in poverty and discouragement a few years later.

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Fortunately for us, who are interested in his successes, the French Government published for him at the time of the award a book setting forth in detail his experiments and results, so that we are able to know more of these than we usually do of such an early process. It proves to be exactly the same process which is used in the gigantic twentieth-century enterprise of canning goods to be carried round the world and kept, if need be, for months and years without danger of change or decay.

François Appert had no convenient tin can in which to seal his goods. He packed all sorts of food in glass or china containers, poured in sufficient water to cover them, and then placed them in a bath of water which was gradually heated to the boiling point, keeping them in this bath for varying lengths of time. While still hot they were corked and sealed. Perhaps you will say that there is nothing new or surprising about that, for which any reward should be offered. It is done in many kitchens every autumn when the fresh fruits come in and are preserved for the winter. No, it is not new or surprising now; it is the common and accepted method. But this is the twentieth century, and our French scientist was working in his laboratory in 1800. It is because Appert worked out this process so patiently and thoroughly in his workroom that we of to-day can do it so easily and naturally in our kitchens. The tests took a long time, for different temperatures and methods had to be worked out. Then the jars must be left closed

for months or years to prove the success or failure of each separate method. But by the time a dozen years had passed Appert had learned the best ways and was able to show many kinds of food which had been put away long before and yet came out as sweet and good as when they were placed in the jar.

Appert saw that the success of his results depended on the complete shutting out of air. He reasoned, as did all scientists of his time, that air must cause the decay of fruits and vegetables. His process was right; but it was fifty years before the famous French scientist, Louis Pasteur, made his remarkable and epoch-making discovery that it was not the air which made the trouble, but the tiny living organisms which lived in the air. Appert had done the thing in the right and only way, but he had explained it wrongly. The result was the same so far as the success of the process went, for the food *was* preserved. But the greater scientist, Pasteur, in explaining the laws that governed the growth of bacteria and germs, revolutionized medical science and brought in a new era of intelligent and scientific food preservation, for which Appert with his clever methods was the forerunner. There is probably no greater day in human history than the one when Pasteur showed that changes which took place in foodstuffs when they were exposed to the air were due to the action of tiny forms of life. If these were removed by heat, and if air was shut out at the same time, the food would not decay until it was

opened to the air and they were thus let in again. Pasteur was given a prize for this discovery in France in 1860. Yet it is only now that we are beginning to realize what a tremendous change his contributions made to the sum of human knowledge and to the methods of human life, from the pasteurizing of milk to the sterilizing of the surgeon's instruments.

It is always interesting to see how two inventions, each of which will help the other, often emerge at about the same time. While Appert was working with his glass and china jars a mechanic called Peter Durand was making the first tin containers across the Channel in England. His first tin can was shown in 1807. It was a crude affair, heavy, made by hand, and with a method of putting on the head which was both clumsy and insanitary. But it was a tin can!

Appert's process was patented by an Englishman within a year of its announcement in France. It was in England that the first American manufacturers learned the art of canning, and probably became acquainted at the same time with Durand's tin can. They took both promptly back to the United States. In 1819 Ezra Dagget and Thomas Kensett, both trained in England in their trade, began to can salmon, lobsters, and oysters in New York. In the following year two other men, Underwood and Mitchell, were canning fruits in Boston, and in their advertisements is found the first use of

the word 'canister' describing the sealed container in which the products could be purchased. This was shortly abbreviated with American speed to the name 'can,' and the enormous canning industry of the United States was launched.

It is not, however, because of the size of the industry that we pay our tribute to the tin can and its contents as worthy of a place in our list of important discoveries. The effect on the life of man has been far-reaching and epoch-marking. So long as man depended on local and seasonal food he was limited in his movements. He could dwell only in regions where there was a fairly constant supply of all the varieties of food needful for his continued health. He could travel and explore for only such distances as were permitted by his food supply. His cities could be only so large as was permitted by the capacity of the surrounding country for their feeding. All these conditions exist and have a considerable effect on man's life to-day. But with the knowledge contributed by Pasteur and the practical method of applying it invented by Appert, both supplemented to-day by mechanical skill in turning out huge quantities of tin cans at low cost and preparing foods in quantity, man's freedom of movement has been vastly extended.

Napoleon would have thought himself able to conquer and hold indefinitely the control of the world if he could have been sure that his armies could be fed at a distance from their native fields of supply.

Columbus was limited in the range of his voyages by the amount of food he could carry in the hold of his vessel. The great explorers were hampered in their early expeditions by the way their men fell sick if they did not have fresh food. Read the story of early voyages and see how men died of scurvy. Peary, Amundsen, and Scott have been able to fulfil the dream of centuries and reach the poles of the earth because they could carry in the tin can sealed and condensed foods which would sustain them to their journey's end. "Canning," it has been said, "more than any other invention since the discovery of steam, has made possible the building up of towns and communities beyond the bounds of varied production."

Will you not join in paying tribute to that humble servant of mankind, the tin can?

THE ROMANCE OF THE WHEEL

Father Nile : Wind against Water

A SAVAGE man, clad only in the skin which he had stripped from some animal, pushing at a rock too big for him to lift or tugging at a load too heavy for him to carry—that is our first picture of a man at work.

How small and helpless that first man seems as we think of him, standing in a wilderness, with no history behind him, no experience to guide him, but only his strong body and such wits as he possessed with which to conquer the world before him. Conquer it he must, for without food and shelter and warmth he would die. The world was full of treasures which could be turned to his comfort and convenience ; but how was he to know it ? There was no key to its treasures, no guide to his resources. The marvel is not that he was slow to find out some things, but how swift he was, in spite of untrained brain and hands, to master those things which would serve for his necessities.

That savage man standing before the load too heavy for him to move is our first picture, a man with only his limbs as tools. He could travel only as far and as fast as his legs could carry him. He could lift only so much as his arms could raise and

carry; he could push only as hard as they could push. There lay the stone he wished to move, and he could not stir it.

Perhaps this ancient hunter picked up then a fallen branch and put one end of it under this big stone, and the stone stirred a little under his pressure. He was excited. He tried a shorter stick, and it did not work at all; a longer one, and it worked even better. If there happened to be a smaller stone lying next to the big one and he laid his long stick or log across it, he may have found that by putting his own weight on the end of the log he could raise that stone without straining his muscles at all. If he did this he had taken a big step upward from the level of the wild animals that roamed the same forests, for he had found out a law. He had discovered the principle of the lever, by which a small weight or force applied at one point can be made to move a much greater weight at another point. He did not know it was a law. It was many hundreds of years later that the Greek inventor Archimedes, seeing the amazing possibilities of that law, put it into words and exclaimed, "Give me but a place to rest my lever upon and I could move the world!" It was a great moment when Archimedes found out and formulated the law of the lever; but was it not a greater moment when our hunter, wanting to do something that was beyond his own strength, made all unknowingly a lever out of a log and moved his rock? He was the fore-

runner of the men who lifted the huge slabs of stone to build the Pyramids of Egypt and of the twentieth-century engineer who swings his steel frame to the top of a skyscraper. It was because he would not be 'downed' by a task he could not accomplish that he found out a tool with which to do it.

Perhaps the load which our hunter wished to carry to his cave-home was the carcase of a wild beast slain for meat. A pair of poles dragged along the ground helped him to carry it farther than he could have supported it on his shoulders. But a long, rough tree trunk dragged over the uneven ground rubbed along its whole length for every inch of the way, making the journey heavy going for the weary hunter. Some day the stick happened to be a smooth, rounded branch, set crosswise across the path, and it rolled easily where the flat stick had been hard to drag. Far off, in the dim ages of which we can only guess the story, there was hewn out a solid 'chunk' of wood, round, cut from the end of a log. Some man, brighter than his fellows, after rolling loads along on tree trunks until his back was wellnigh broken, hewed out two of these round slabs, stuck a piece of wood through the centre of each, and lifted his load off the ground so that it should no longer drag and rub. Those were the first wheels set with an axle; that was the first cart.

Again man had found out how to get round a natural law, the law of friction. 'Friction' simply

means the rubbing of one surface upon another. Friction may be useful to man in many ways. We should all slip and slide as we do without skates on ice if it were not for friction. But that prehistoric man was pitting his strength against that rubbing. The power which came from his own muscles was set against that endless rubbing of the load on the ground. When he lifted the load off the ground, he gained much. A sledge on runners goes more easily and swiftly than a piece of board dragged on the ground. But when he put a curving wheel under the load and made that wheel turn on an axle, he had doubled the gain. He had added the power of a wheel, working on the principle of a lever, to take the weight of the load, to the advantage of lifting his clumsy load off the ground so that one flat surface should not drag over another flat surface.

It is one thing to learn these laws as part of a lesson from a physics book ; it was quite another for the early man to find out one by one, with many failures and few successes, devices by which he could make a little easier the back-breaking labour which was exhausting his strength. We honour the men who had the wisdom and understanding to perceive and to formulate the great laws on which the universe is built. Let us not forget to honour that hard-working pioneer inventor who had the wit to make and to use a wheel.

FATHER NILE

"The flood is coming, the flood is coming. Father Nile is rising," the children in old Egypt used to cry, and all the people would drop their work and rush out to see the giant river begin to stir and lift itself between its banks.

For ten long months the land had been drying up under the parching heat of a southern sun. Now it was summer and the River-god who had never failed them yet would rise from his quiet, even habit of flowing in his river-bed and would sweep out over the land, flooding wide reaches of country with his life-giving water. For fifty days he would bless them with his gifts, and when he went back to his peaceful rest between the banks which he had built for himself the land would be covered with a rich, thick black mud whence would spring fruits and flowers and grains, with which the people could comfort themselves until in another year he should bring them his precious gift of water again.

To those who have their spring and summer and autumn rains and their winter snows, living as they do in a land where water is a familiar and constant blessing, a flood is a break in Nature's routine and a calamity to mankind. Because they do not expect or need its sudden supply of water, it brings only distress and loss, sweeping away the homes built in its path and destroying crops. But Father Nile was no such unwelcome visitor in the parched

land of Egypt. Without his forty-foot rise each year the country would have been a desert like the Sahara. No wonder they worshipped him and pictured him as a friendly and genial god, crowned with fruits and green leaves, with elves or sprites playing happily over his huge form.

But while the sweep of his arm was broad it did not cover the whole land. And while his stay was blessed as long as it lasted, there were ten months when he slept tranquilly in his narrow bed. Where Father Nile's work stopped man's work began, and hard work it was.

This precious water which came for so short a time must be stored. So slaves were set to building earthworks which should hold it as in a pond or lake, so that it would not all run away into the sand. It must be carried to the homes and gardens and farms which lay beyond the flooded region. So slaves were put to carrying it in jars on their heads. Human labour was cheap in those days. The kings and nobles of Egypt had hundreds upon hundreds of men and women whom they thought of as mere chattels, human machines which existed only to work endlessly in their masters' service. Old Egyptian carvings in stone show rows upon rows of slaves carrying water-pots on their heads.

But even slaves and slave-drivers are men, with the wits of human beings, not mere animals to toil endlessly at a task without hope or thought of change. Some genius who had to lift water day

after day from the low level of a ditch to the higher level of the fields hung his bucket on the end of a pole and put his weight on the other end of the pole. The lever was in use again, you see. The bucket swung easily up into the air, and its load was tipped over into the channel where the man wanted it to flow. The whole land of Egypt along the banks of the Nile was interlaced with an intricate system of canals and pipe-lines and well-sweeps (poles with buckets), set singly or in pairs, to lift water from one level to another. But still all the lifting had to be done by men ; all the push, wherever it was applied, came from their muscles.

Then some slave, brighter or maybe less strong and therefore thought by his master to be lazier than his fellows, watched in his moments off duty an Egyptian chariot driving swiftly by on its smooth-turning wheels. He took a wheel which had fallen off an old cart, and set it in place of the pole on a well-sweep. The buckets came up even more swiftly, and the labour was less. A man pushes backward and forward, backward and forward, with a stop between each two strokes and a loss of power with each start and stop. But the gain of a wheel is that it turns round and round without stop or start. Here another chapter was added to the romance of the wheel, for its swift, smooth motion was made not simply to carry men and loads over the ground, as it had done in the cart or chariot, but to do work in lifting weights. Still the wheel

had to be turned by man's own hand or by an animal which he might use as a substitute. As a matter of fact, it was done in Egypt chiefly by man's own muscle, for men were numerous and human labour was cheap.

It was many hundreds of years before the next big event. It occurred when a man who had real inventive power, a man who stood head and shoulders above his neighbours in brain and skill, watched the swift current of a stream as it swept everything along with it, and set a wheel in it to let the water turn the wheel. Then he widened the spokes of his wheel into paddles, like the oars of his boat, so that they should catch the pressure of the water. When man first let the natural weight or pressure of running water turn a wheel for him, and then fastened that same wheel by its axle to the device by which he was lifting water in buckets, he had won a victory which might well be heralded down the ages. He had made a machine which would 'go' by itself. He had gone beyond the use of tools for which he must supply the motive power and even of machines like the lever in which he must supply part of the force while depending on the laws of mechanics to do the rest. In the water wheel he had made a machine in which water itself did the work of lifting water, while he stood aside and watched it done.

At that moment the age of self-working machinery began. In that moment man lifted himself from the

level of a toiler depending for his results on his own or his animals' labour. For human or animal work he substituted the work of a natural element, falling water. The glorious day in which man was to be delivered from the slavery of toil had begun. He had advanced far along the road to directing a task with his brains instead of striving at it with his muscles.

WIND AGAINST WATER

Five hundred and more years ago there dwelt in the little village of Alkmaar, in northern Holland, a man called Florent Alkmade. He was a prosperous citizen of the town, a blacksmith and a well-to-do farmer who owned much land.

Farming was not easy in the Netherlands in those days. Indeed, life there has never been easy since the days when the Saxon and Frisian barbarians came down from the north and looked on the shifting, water-swept marshes and, giving to them the name of 'Netherlands' or 'Lowlands,' set themselves to make of them a country of homes. Perhaps it has been the battle which they have always had to wage against wind and water which has given to the people of the little country a force and determination which have shown themselves in all their history. Only a brave and persistent people would have taken a land of shifting sands, where overflowing rivers and inrushing currents of the sea

dispute for possession, and carved out of it a rich and fertile farming land.

Every one knows the story of the dykes of Holland, those high earthworks and barriers of stone with which the sea is kept back from overflowing a land which is in many sections below sea-level. The Cimbrians and Frisians built dykes even while they camped on the higher ground which overtopped the waters, and later generations had added to them till in the days of Florent Alkmade the rivers and the sea were under some control and one might dwell with reasonable safety and comfort behind the circle of reinforced sand dunes which fringed the coast.

But while the sea was shut out the rivers still overflowed their banks and formed a long line of perpetual marshes. Where there should have been stretches of green, fertile fields, producing crops, there were acres upon acres of boggy marsh. As Egypt in the days of the Pharaohs had suffered from lack of water, so Holland in its early history was wellnigh swamped with it.

Florent Alkmade did not stay always in his own little village, but journeyed on business, not only to the cities of Holland, but to Paris and southward into the rich farming regions that stretched across middle Europe. He saw the prosperity of those lands, and thought of his own marshy acres which would be rich and fertile, too, if he could only drain off the excess of water there.

In Paris he heard from a traveller who had been

in Bohemia of a new device which a man had invented there by which a wheel was set up in the air and made to turn by the blowing of the wind, so that it could by its revolutions be used to pump up water from a well. Now Alkmade was a practical mechanic. He knew how a pump could be made to draw water out of the ground. He used crude pumps on his own estate, but they worked hard and drew up little water. Against the sweeping of water into the marshes as it came from the rivers, the work of a hand-pushed pump would be like child's play. Holland in the fifteenth century had no army of slaves to be stationed all over its wide marshes in order to work night and day against the rise of its waters.

Another man might have scoffed at the idea of using the wind, but Alkmade was a Hollander, with a Dutchman's familiarity with boats and water. From his childhood he had known how to run up a cloth sail in his boat and tack to and fro on the wind-swept inland lagoons. A sailor himself, he knew well the power of wind. But for wind to turn a wheel and the wheel to run a pump—that was a new idea. A less clever man would have thought it a wild idea. A man with a smaller problem would have thought it easier to keep on pumping with the old hand labour or with an animal circling round and round in a treadmill turning a wheel. But no man or animal could ever drain his broad acres. Yet if they were drained he believed

they could be made every bit as fertile as the carefully nurtured fields of France.

When Alkmade came home from Paris he said nothing about this new machine of which he had heard. He knew his sober, unimaginative neighbours too well to think that they would do anything but scoff at the idea of wind pumping water. But he set to work to make a toy wheel with sails on it. At least he could test that idea for himself.

It took some time to get the sails at the right angles; but at last he got a little wheel which spun round in the wind as if it had learned the secret of perpetual motion. He called in some of his neighbours to see it. They admired his skill in making the toy, but laughed at the wild idea of such a machine doing real work.

"It all goes to show," they said, "what travel does for a man. Florent was a good farmer and an industrious, hard-working blacksmith before he went journeying off to the city. Now he thinks he knows more than his fathers did before him, and he is wasting his time playing with wind toys. Fancy harnessing the wind to run a pump! Who ever heard of such a thing?"

But in spite of the fact that no one in Holland had ever heard of such a thing Florent Alkmade kept at work on his wind wheel. After he had worked out the idea with his model he built a larger wheel in which four sails took the place of spokes, and set it on an axis so that the wind would

strike the sails and keep the wheel turning. If he could get a wheel that revolved in the wind it would be a fairly simple matter to connect it by

DUTCH WINDMILL

A Dutch farmer harnessed the wind to combat the water, and thus two ancient foes of Holland were pitted one against the other.

smaller wheels with his pump and let the motion of the wheel keep the pump going.

At last he set up his big wheel. It would go only if the wind blew on it from one quarter. So he set it, as all the windmills in Holland were to be set for many, many years, for the prevailing north-west wind. When it worked, and the first

water had been drawn from the pump by its turning, he called in his neighbours again and set it going.

A Dutchman may be slow in his ways and hard to convince, but when he sees a good thing he knows enough to appreciate it. Those stolid Dutch farmers had spent all their lives battling against two elements: water and wind. As fast as they built up dykes of sand to keep back the waters, the winds sweeping down from the north-west lifted the tops off the dunes and let the waters rush in again. When they saw their two ancient foes put against each other, the wind in its sweep harnessed to draw the water from the ground, they laughed at the humour of the thing, and clapped their neighbour Florent on the back for his cleverness.

Before Florent died, not only were these windmills set up all over his own lands, keeping the marshes drained so that they became in their season fertile for crops; but his neighbours had copied his plan. Their sails, too, were revolving in the breeze, and people were coming from all over Holland to see the sight. Alkmade set up his first successful windmill in 1408. Before the year 1500 Holland was dotted with windmills, those windmills which for four hundred years have made the country famous for its picturesqueness. The swamp lands were being turned into fertile farms; the people were prospering. Man had won another victory in that he had set two forces of Nature against one

another in his machines. With wind working for them in their battle with the waters, the men of Holland had gained a sure ally in their conquest of Nature.

The next step came when man began his second conquest of fire, and used it for power, setting steam to turn his wheels and do his work for him. That was not to happen for another two hundred years. With the story of fuel turned to power to drive his machines, the romance of the wheel will be complete.

FROM FIBRE TO CLOTH

A Chinese Princess and her Silk Dress: A Secret Kept for Three Thousand Years: When Colour Came

When Adam delved, and Eve span,
Who was then the gentleman?

IT is an old English rhyme which credits the first woman, Eve, the mother of the race, with being the first spinner. If the first woman did not weave or spin, we may suppose that some of her daughters or granddaughters or great-great-granddaughters did, for weaving is an art that was practised so far back in the childhood of the world that no one tries to trace its beginnings. Before the early man of the North made for himself a fur-lined garment from the skin of some animal, the woman of the South had plaited long grass blades or the tapering leaves of reeds and rushes into a basket in which to carry more things than her two hands could hold, a mat to cover the damp, hard floor of her cave or hut, and an apron or skirt with which to clothe herself.

By the time that Jubal, the brother of Tubal-cain, had become a herdsman and the father of all herdsmen, his mother Adah and his wife and daughter had doubtless become expert in weaving plant leaves or fibres into the coverings and mats

for the tents in which they dwelt. Perhaps they had wound the fibres into a coarse thread which they pushed through holes punched in the edges of the tent coverings to hold them together.

It was in those very early days that woman began to concern herself with the clothing as well as the food of her family, and practise with her poor tools the arts which were to be one of her later glories, for women have been the creators of the beautiful arts of spinning, weaving, and dyeing. It was a woman who first split the fibre of the flax plant and twisted it into thread. A woman, the wife of a herdsman, wandering in chilly days on the high hills, took strands of the wool from the coat of a sheep and made of it a warm coat for her child. A woman, wishing to twist the hairs of the sheep or the fibres of the flax plant into a long, firm thread, hit on the idea of putting the bunch of loose, short pieces on a stick and spinning it round and round so that she could draw out swiftly a long, hard-twisted thread. She was the inventor of the spindle, which was turned at first by hand and later by the spinning-wheel. It was the love of beauty in a woman which made her grow weary of the plain, dull colours of the wool and dip into a bath of plant juice the threads which she was to use, so as to give colour and beauty to her work.

These women of whom we speak lived in the days of wandering tribes. With the dawn of agriculture and the making of homes, the chance came for

women to plan their work. They need no longer be satisfied with only such coarse materials as they might find in the fields. They could cultivate flax or cotton plants for their cloths of lighter weight, and breed sheep to provide for wool. The calling of the herdsman became doubly profitable when the coat as well as the meat of his animal was valuable in exchange. There is a record in the Bible telling how Mesha, the King of Moab, who was a sheep-master, paid his tribute to the King of Israel in the form of the wool of a hundred thousand lambs and of a hundred thousand rams. The skill of women in making woven goods of all kinds had given to raw wool a commercial value.

Again in the Bible we come in the Book of Proverbs upon one of the most beautiful pictures of the ideal woman of the period several hundred years before the Christain era, when all the arts and crafts of the household were under her capable direction. These are given as the "words of King Lemuel," which his mother taught him, so that he should know what kind of a wife a king's son should seek out.

> She seeketh wool, and flax, and worketh willingly with her hands.
>
> . . . . . .
>
> She layeth her hands to the spindle, and her hands hold the distaff.
>
> She stretcheth out her hand to the poor; yea, she reacheth forth her hands to the needy.

She is not afraid of the snow for her household: for all her household are clothed with scarlet.

She maketh herself coverings of tapestry; her clothing is silk and purple.

A CHINESE PRINCESS AND HER SILK DRESS

If you were a little Chinese girl tending your mother's silkworms you might weary of the task of gathering endless piles of fresh mulberry leaves for the hungry little creatures to eat. But if you complained to her she would say to you: "If the great and worshipful Empress Hsi-Ling-Shih could tend silkworms with her own hands when she was a young girl, is there any reason why an ordinary little girl like you should not?"

Then you would bow very low in your shame and say, "No, honoured mother, I will do it gladly."

But when you had finished your work perhaps you would ask her to tell you again the story of the Empress and her silkworms, and this is the tale that she would tell.

"Long, long ago, when all the rest of the world was barbarous and savage, the Chinese people were wise and clever in many things. That was a Golden Age in our land, when the Yellow Emperor, Hwang-ti, who was directly descended from the gods themselves, ruled the land. Hwang-ti was wise and kindly in his rule and did many things for his people. He gave the merchants a true system of weights and measures, so that when the poor people bought tea

or rice they could always know how much they were buying and would not be cheated in the prices. He taught the men of the river how to build boats, so that all China was united by the boats which went up and down its great rivers. During his long reign the first metals were discovered and the first dishes were made out of pottery. All the land prospered in the time of the great Yellow Emperor, child of the gods, who lived for a hundred years and blessed the land with his wisdom. But though Hwang-ti was the greatest of emperors, with all his wisdom and all his labours at affairs of State he did not do as much for the future welfare of his country as did his fair young wife, Hsi-Ling-Shih, who sat at home in her garden and took notice there of an ugly little worm.

"The garden was full of mulberry-trees. That was why the silkworms lived there, for they love the mulberry leaves, as you know well, little daughter. The young Empress, who never set her hand to any work, came and sat in the garden under the trees to shelter from the scorching heat of the sun.

"One day when she entered the garden she stopped and listened, for there was a sound in the trees as if rain were falling. Yet the sun was high in the heavens. She listened and watched, and then she saw that all the little worms which she had watched idly as they climbed on the branches, and had disliked because they ate the leaves of her pretty mulberry-trees, had stopped eating and were

making cocoons for themselves. Her attendants told her that they would keep on with the spinning of their cocoons for three days and three nights. Then, when they had shut themselves completely in from the air and wind and sun, they would sleep for a full moon, after which they would eat a hole in the end of the cocoon and fly out as beautiful winged moths. Hsi-Ling-Shih had never seen a butterfly come out of a cocoon. So she watched for the three days while the busy little worms worked, and then, when the three days were ended, and the garden was still again, she began to count the days until the moths would fly.

"Sure enough, when the moon was again at the full, out they came, hundreds of soft-winged flying creatures. But Hsi-Ling-Shih was not so curious about the silk moths as she was about this house or cover which they had spun for themselves. Dozens of the empty golden-yellow cocoons lay on the ground. She picked them up and studied them and drew out the soft silky thread of which they were made. 'What a wonderfully soft, fine thread this is,' she said to herself. 'It is finer and softer than the fibres of which my robes are woven. If we only knew how to make a thread so soft!'

"Hsi-Ling-Shih played idly with the cocoons in her hand, testing the thread and noticing how strong it was, and rubbing it across her hand to feel how soft it was. Then all at once an idea came to her. Why should she try to think of a way to make

thread like it? Why not take the very thread which the little worm had made and use it to spin and weave a dress for herself?

"When the next time came for the silkworms to spin the young Empress went again to the garden, but this time it was not to watch. This time she took the cocoon as soon as it was finished, before the moth had cut a hole in it to get out, and she tried to unwind the silky thread as it was wrapped round and round. At first it broke in her hands, but she soon learned that if she dropped it in hot water, which would kill the little worm, the silk would be much softer and easier to unwind.

"The silk which came from one cocoon was a very small quantity, but she set all her attendants to pick up cocoons, until there were piles upon piles of them. When they had been boiled she sat and wound the silk on a round stick, one length after another, until she had many, many yards of the soft stuff. Then she took it to her loom, where she was accustomed to the weaving of flax and wool, and wove a tiny piece of cloth from the golden, shining mass of silk.

"So that is why we go each year, little daughter, at the time when the mulberry leaves come out, to the temple, you and your grandmother and your father and your uncle and I, to worship the Empress Hsi-Ling-Shih, who is the goddess of silk, for with her own hands and by her own quick wits she found out the secret of the spinning of silk and taught it to her people."

"Did every one keep silkworms after that?" the little daughter might ask.

And the mother would reply: "Yes, when the ladies of the court heard that the Empress was keeping silkworms they all wanted to be in the fashion. The Empress used to go out into the palace garden with golden tools to cut the mulberry leaves and a golden dish on which to gather them; and the other ladies of the court were permitted to go out with silver tools and silver dishes to help to collect the leaves. What the people of the court did all the people wanted to do. So before long in all the land the people were breeding silkworms and reeling the silk on spindles for their looms, and all the rich folk were wearing silk gowns and silk girdles and using silk coverings in their houses."

"But does not every one in the world keep silkworms?" our little Chinese girl might ask. Then her mother might tell her another story of how the secret of the silkworm and its spinning was kept in China for three thousand years.

A SECRET KEPT FOR THREE THOUSAND YEARS

Can you think of a whole nation keeping a secret for one hundred years or two hundred years? Can you think of men and women and children all knowing that secret and of inquisitive visitors from other lands moving about in the market-places and towns

and trying to spy out that secret, yet of no one revealing it? That is what the people of China did with the secret of the silkworm for thirty long centuries—three thousand years.

So proud were the Chinese, in the first period of silk culture, of this wonderful new fabric which they had created that they guarded their secret most carefully, and laws were made by the rulers forbidding anyone to take silk out of the country. Foreign traders might come and buy pottery and tea and rice, ploughs and hammered metal and whatever else of the Chinese craftsmen's products they might desire; but on the shining webs of soft silken fabric they might only gaze with covetous eyes. Those were not for sale.

The lure of trade was too strong to keep merchants from smuggling silk cloth over the borders. Silk *did* come out of China, even in those years when the laws were strict. More and more came out in later centuries, as the intercourse with other nations increased. There is an old road cut across the mountains from Persia to China. Some say it is the oldest road in the world. It began as a footpath, wide enough only for a single file of men to walk along it. Gradually it was hewed out of rock and stone and laid across trackless plains until it became the greatest caravan route in the ancient world, the road from the Near East to the Far East, the road over which the peoples of the Mediterranean travelled in the quest for the beautiful products of the craftsmen of China and

NATIVE WEAVERS IN NEPAL

Photo Johnston and Hoffmann

It was a Chinese princess who finally broke the law. She was to be married about A.D. 120 to an Indian potentate, the King of Khotan. He knew that a Chinese princess would be accustomed to dress only in silk, and sent word to her that while India was famous for its cotton it could supply her with no silk. Daring greatly, the princess concealed mulberry seeds and silkworm eggs in her headdress when she set off on her bridal journey to her future home, and succeeded in passing the frontier without being detected in an offence which was punishable by death. Arrived in her adopted country, she began to cultivate silkworms. But Chinese ambassadors to her husband's court, seeing what she had done and powerless to punish her when she was queen of another land, resolved that still the precious secret should be kept. So they told the King that his wife was harbouring venomous snakes, and the King promptly had the 'snake-rearing' house destroyed by fire.

The secret did filter into India in the early years of the Christian era, and in A.D. 289 it is known that four Chinese girls were sent to the neighbouring country of Japan in order to teach the culture of the silkworm there. But as late as A.D. 500 silk-making was unknown in Constantinople, then the leading capital of the Western world. The Emperor Justinian, ruling from Constantinople, was enterprising and clever in fostering commerce. Like Alexander the Great he was always seeking out some

new thing that was done in other lands. Two Persian monks of the Nestorian order of the Christian faith returned to Constantinople after living for long years in the Chinese Empire, and learning, as long residents there could hardly help doing, the whole method of silkworm rearing and silk culture. The Emperor heard their story and was greatly excited by it. He made them promise that on their next visit to Constantinople they would attempt to bring him out some silkworm eggs.

The story is that in the year 555 these monks did bring out silkworm eggs concealed in their hollow bamboo walking staves. In Constantinople the eggs were carefully tended under the monks' direction. The little worms spun their cocoons and came out as moths as punctually as if they had not been carried half round the world. So the Emperor had his silkworm culture safely started. The whole process was carried on in his own palace, even to the setting up of looms where women could work at the weaving within the Imperial walls and under his own personal observation. But no secret could be kept in the sixth century in Constantinople, even in an Imperial palace, as it had been kept in earlier centuries in remote China. Although Justinian reserved a monopoly for himself in silk stuffs, allowing no one else to manufacture them, the industry was soon to be found elsewhere in the Western world.

From the eggs in that bamboo staff came the beginning of a great industry which flourished in

southern Europe and especially in and near Venice for the next twelve hundred years. At last the three-thousand-year-old secret was ' out.'

WHEN COLOUR CAME

Our next story belongs to modern times, within the last seventy-five or a hundred years. To arrive at that story we must travel across a bridge of a thousand and more years, during which two groups of arts were developing, both of which were to serve in the fashioning of clothing in the world of to-day.

One was the art of machinery. Skill in the weaving of cloth grew apace with the invention and introduction of machinery in the eighteenth century. If we were to date the periods of cloth manufacture we should find that from the dawn of history to about the fourteenth century A.D. the implements of spinning all over the world were the simple, primitive ones of the distaff and spindle. The Chinese weaver of silk, the Hindu weaver of cotton, and the workers of the early Middle Ages in Europe would have found their tools and their looms practically interchangeable.

Until the middle years of the eighteenth century, the old-fashioned spinning-wheel and the hand-loom were the only implements used by the spinners and weavers of England. But men were beginning to ask themselves whether some method might not be

devised by which the wheel could be kept turning and the shuttle moving more easily than by the toil of one pair of human hands. In the previous century, a French naval officer called de Gennes had invented " a machine for making linen-cloth without the aid of a workman," but his idea was never successfully applied. Then, in 1733, John Kay, of Bury, Lancashire, introduced a new sort of shuttle, known as the ' fly '-shuttle on account of its superior rapidity of movement, and twelve years later, in partnership with Joseph Stell, he patented a loom which might " go or be worked by hands, water, or any other force." A much more memorable moment in the history of industrial science came in 1764, when James Hargreaves, a hand-loom weaver who was also a carpenter, and who lived near Blackburn, invented the ' spinning-jenny.' The idea is said to have been suggested to him by the sight of a spinning-wheel, overturned by one of his children, continuing to revolve horizontally while the spindle revolved vertically. With the aid of the spinning-jenny twenty or thirty threads could be spun at the same time as quickly and as easily as one could have been spun without it. When this fact became known to Hargreaves' fellow-weavers they were greatly alarmed, for they feared that the result would be unemployment and lower wages in their craft. So they broke into the inventor's house one day, and destroyed his apparatus.

The threads stretched on the loom before the

weaver begins his work are known as the 'warp,' while the threads thrown by means of the shuttle are called the 'weft.' Now, the thread spun by the spinning-jenny could be used as weft only, not being sufficiently tough and strong for the longitudinal warp. And now comes another great moment, when another clever man had an idea destined to influence the lives of millions of his fellow-men: now comes the story of the barber's apprentice who died a knight and the possessor of great riches. Richard Arkwright (1732–1792) was the youngest of a family of thirteen children, whose father and mother were too poor to give them anything beyond the most meagre education. Young Richard was apprenticed to a barber, and by the time that he was twenty years of age he had set up in business for himself at Bolton, where he not only shaved his customers' chins and curled and powdered their old wigs, but sold them new wigs, dyed by a new process which he had invented. Thus he prospered greatly, and was able, after a time, to abandon his barber's shop and turn his attention to cotton-spinning. The spinning-jenny interested him so much that he began to make experiments to find if it were not possible to produce a similar machine which should spin stronger thread, thread strong enough to be used as warp. With the aid of a Warrington watchmaker, John Kay (*another* John Kay, probably related to him who invented the fly-shuttle), he planned and set up a frame upon which, for the

first time in the history of weaving and spinning, the necessary strong thread was mechanically spun. Arkwright's first mill, established at Nottingham in 1768, was worked by horses: three years later he started one at Cromford, in Derbyshire, where power was supplied by a water-wheel. He, also, was the object of much popular indignation, and his factories and machines were more than once destroyed by furious crowds. But he lived long enough to triumph over all handicaps and to introduce steam-power at his Nottingham mill in the year 1790. And now comes yet another great moment, and another story, the story of a quiet and scholarly country clergyman, the Reverend Edmund Cartwright, the whole course of whose life was altered by a visit he paid to one of Sir Richard Arkwright's great mills. In the year 1785 Cartwright invented a power-loom which, despite all its imperfections, was the direct forerunner of the power-loom in use to-day. Full of enthusiasm, he started mills at Doncaster and Manchester, only to see them set on fire by angry mobs who looked upon him as their worst foe. But Cartwright persevered. He turned from cotton to wool, and designed a wool-carding machine; he associated himself with the researches and experiments of the Irish-American engineer, Robert Fulton, the first man to apply steam to navigation with success. Although none of his inventions was very profitable to Cartwright personally, he did not die poor and disregarded as some inventors have died,

for Parliament made him a grant of £10,000 in the year 1809.

The last story which we will relate here of the development of machinery in the English cotton and woollen trade is the story of a fiddler who found out a new way of making muslin. Like Hargreaves and Arkwright, he was a Lancashire man, and, like them, he was born in very humble circumstances. His name was Samuel Crompton, and he was born at Firwood, near Bolton-in-the-Moors, in the year 1753. Left fatherless at an early age, he helped his widowed mother by spinning yarn; a little later he got a post as fiddler in a theatre at Bolton, and divided his time between fiddling and spinning. Crompton was so constantly fretted by the snapping of the ends of the yarn with which he worked, that it occurred to him that he might improve upon the plan of Hargreaves' spinning-jenny in such a way that the troublesome yarn should cease to snap. After he had toiled for five years he completed a machine which spun yarn fine and soft enough to be used in the manufacture of muslin. Master-spinners, eager to learn his secret, besieged his house, and, as the principle of the thing was so simple that any expert could grasp it at a glance, the unfortunate inventor, who was too poor to take out a patent, had to mount guard over his machine night and day. Finally he divulged his secret to a Bolton manufacturer who, one is sorry to know, did not reward him as generously as he had promised to do.

The spinning-mule, as it came to be called, was soon extensively used in England and in Scotland. Encouraged by the Parliamentary grant to Cartwright, Crompton collected evidence as to the enormous number of his machines actually in use, and appealed for State aid. Parliament, however, voted him only half the sum it had given to the clerical inventor, and poor Crompton returned to Bolton a bitterly disappointed man.

From the discoveries of these four clever and resourceful men, the enormous cotton and woollen manufacturing trade of Lancashire, Yorkshire, and the Scottish industrial centres arose. The great moments in their lives are links in one continuous chain connecting the most up-to-date textile machinery with the simplest wheel and loom used by the women of the antique world.

The chemist was to make the other great contribution in the business of clothing the world. A chemist's assistant, seventeen years old, working overtime in a London laboratory, made in the year 1856 a discovery which deserves to be ranked as one of the great moments of science in the history of the modern world.

Curiously enough, while all these advances were being made in the art of weaving cloth and spinning cotton, the art of dyeing these fabrics was practically at a standstill. Plants, such as indigo and madder, lichens such as archil, animal substances such as cochineal, minerals such as cinnabar, were

the chief sources of dye-stuffs till well into the nineteenth century. With these limited and imperfect materials the weavers of Europe produced charming colour-effects, as we may see for ourselves if we examine the brocades and chintzes and block-printed calicoes in the textile section of a great museum; but no inventive genius had yet turned his attention to the possibility of using combinations of chemicals in order to produce a wider range of colours in much larger quantities.

William Henry Perkin was an English lad who had a passion for chemistry. At the age of thirteen, in his City of London school, he found that an extra set of chemistry lectures was to be given at the noon interval and promptly enrolled for them, although it meant going without his lunch. At fifteen he left school because he heard that a German chemist, Hofmann by name, was opening a laboratory at the Royal College of Chemistry in London. Hofmann took the eager boy into his laboratory and set him to work at research problems. Chemists in that period were deep in the study of the way all substances were composed of the various elements in different combinations, and Hofmann set young Perkin to solve the problem of how artificial quinine (which might be substituted for the natural quinine found in the bark of a tree) could be made from coal tar, which seemed to have many of the same elements.

Coal tar is a black, sticky stuff which is left when soft coal is burned in an enclosed vessel. It had been considered by coke-makers and gas-makers, who burned coal in this fashion to get coke or gas, to be a useless waste product, and rather a nuisance besides, because it got into their pipes and clogged them up. For a hundred years it had been thrown away.

Perkin became so interested in his job that he set up a private laboratory of his own, where he could work in the evening and during holidays. It was during the Easter holiday of 1856 that he was heating some aniline oil and got a black, tarry mixture in his test tube. He was startled to find that when he poured in alcohol to wash out the tube a beautiful purple mixture appeared. This was the first of the aniline dyes of which there are now hundreds made in chemical factories. To this beautiful purple colour Perkin gave the name of 'mauve,' from its resemblance to the hue of the mallow-flower, called in Latin '*malva*.' It was with Perkin's mauve that the lilac-tinted penny stamps of Queen Victoria were engraved.

Any moment is great in which man comes into power as creator in a new field. In taking known substances and so putting them together under the influence of heat that they form an entirely new substance, man is rivalling Nature in the work of creation. Perkin did this in his test tube, and it was a great moment in the history of chemistry and

of man. Ten years later he made his success even more spectacular by manufacturing in the laboratory a 'Turkey red' dye exactly like in composition the dye manufactured from the madder plant. Other chemists were working on the same lines. For forty years it was known to them that when plant indigo was broken up it gave off aniline oil. But how to reverse the process and get the indigo *from* the oil was another matter. Adolf von Baeyer of Munich laboured on the problem of the constitution of indigo for fifteen years, until he solved its secret and was able to make indigo.

Within two years of the discovery by Perkin of how to make alizarin (Turkey red) in the laboratory instead of taking it from the madder root, the madder fields of France were being put to other uses. Nature could not rival man's factory in cheapness and abundance of production.

Before man turned chemist and was able to analyse how substances were made, he had to hunt the world over for his colours. Now he can go into the laboratory and create them. In a commercial list published in a recent year there were recorded a thousand dyes made from coal tar. When the weaver has turned out by machinery yards of fabric of every weight and texture with which to clothe us, the chemist is able at small expense to tint them with a thousand hues. The result has transformed our daily lives. No longer does a king pay royally for precious 'royal purple'; his humblest subject

can be clothed in any colour or combination of colours at a price hardly more than that of the cheapest dull-hued fabrics. In his age-long search for beauty man has come on a secret which gives him the power to create what he sought.

STORIES OF TIME AND SPACE

Berosus the Babylonian: The Water-thief: Galileo and the Pendulum: A Clock to Go Two Thousand Years: Compass and Radio Compass

IN the walls of the canyons and cliffs of New Mexico and Arizona there are to be seen the ruins of prehistoric dwellings, built by a race which lived so long ago that no other record of them remains. The cliff-dwellers who built their homes in the hollows and ledges and recesses of these narrow high-walled canyons, in the far-off days before written history, were probably ancestors of the Pueblo Indians who still dwell in these regions. Their homes were tucked away in the walls, with only a hole and a few slabs of red sandstone to mark them, because they were safer there from attack than in the more open valleys. Those were the very earliest days, before men had any knowledge of tools for building, before they mixed lime into mortar, before they made adobe bricks. They were the days, too, before men kept any count of time.

Yet do you not think that even the cliff man, knowing the daily change from darkness to light, looked up at the sun in awe and worship and watched it follow its daily course across the heavens?

Do you not think that the cliff woman measured the length of the day, when her men-folk were away hunting, by the shadows on the cliff walls? When the men set off for the hunt, it was early dawn. As the sun climbed higher in the eastern sky the dark shadow on the western wall of the cliff began to move downward before the sun's rays. All the morning the shadow crept down the cliff side until at noon the sun stood directly above the narrow canyon, into which poured as much light as ever came within those towering walls. Then perhaps the man came home, bringing the body of some animal which he had tracked and killed for food, and before the shadow crept to the top of the other side of the cliff and darkness fell there would be a rude meal eaten on the ledge in front of the hollow where they slept. The sun is the world's greatest timepiece. The walls of the cliff were the face of the cliff-dweller's clock, while the moving shadow was the hand that told time.

The cliff-dweller had the walls of the cliff on which to mark the progress of the shadows. The herdsman or the tent-dweller on the plains measured time by the shadow cast by a tree or stone. One day, which was a wonderful day in the history of any tribe, a man who was more clever and more resourceful than his fellows, set up a pole where there was no tree or rock and put a stone to mark for all succeeding days the point where the shadow fell when the sun was highest in the heavens. That

was the first time that a man went beyond the provision which Nature had made for him and deliberately set out to divide his days by a regular measure. And if a stone for the shadow at noonday, why not one for early morning, and one for mid-afternoon? In a circle of stones with a stick to throw a shadow, the clock face with its marking of the hours was born. The sundial was the forerunner by many hundreds of years of the clock.

BEROSUS THE BABYLONIAN

Time, except in big sections like morning, noon, and afternoon, mattered as little to the savage man living with his family in a cave as it would to a Robinson Crusoe cast up on a desert island. But when men began to come together in villages and towns and to plan their lives together, it was convenient to have a system with shorter periods. So the face of the sundial was marked with lines at regular spaces to indicate regular intervals of time.

The very earliest records of time-telling come from a wonderful people, the Babylonians, who lived in the rich region east of the Mediterranean Sea between the Tigris and Euphrates rivers. Mesopotamia, 'The Land between the Rivers,' is the name by which we know the then rich, fertile country in which they dwelt. They built houses and walled cities of sun-dried bricks, and their wise men (*magi*)

THE CLIFF-DWELLER AND THE MOVING SHADOW

The sun is the world's greatest timepiece when the sky is clear.

From "Time Telling through the Ages." By permission of the Ingersoll Watch Co., Ltd.

became learned in the ' magic ' of the sun and moon and stars. The sun was their god *Shamash*, and the moon and the planets were also gods. Shamash was the god of order, too, for his priests studying his movements and those of the other heavenly bodies saw that they proceeded in regular courses. Savage man had probably noted that the shape of the moon changed from a thin crescent to a circle and back again, and had perhaps come to count time from full moon to full moon. But the Chaldean and Babylonian priests made careful mathematical studies of all these matters. They saw that the sun changed the points at which it rose and set, travelling toward the north at one time of the year and toward the south at another. They kept a record of the length of the sun's days as it made this yearly journey.

Finally this school of priests made a chart in which they laid out on papyrus, as if they were drawing a map, the facts which they had learned in their sun-gazing and star-gazing. This chart, which is called the ' zodiac,' was round like a wheel, or like the sky as they thought of it, for they believed the earth was flat and the sky was like a great bowl turned upside down over their heads. In the centre of the wheel they put the sun. A little farther out was the moon, moving round the sun in its four phases, new moon, half moon, full moon, and half moon again. Around the edge was a belt divided into twelve sections. These were the

signs or ' houses ' of the zodiac. In them dwelt the fixed stars or groups of stars, each house being named after its leading star or group. It is because seven of the twelve signs bear the names of animals that the zodiac is so called, from the Greek word *zōon*, meaning an animal.

Here we see for the first time the use of the figure twelve, on which our whole system of time-keeping is founded. The Babylonians mapped out a year as having twelve moons or months. They divided day and night into twelve hours each, making a day of twenty-four hours. Then they divided the hour into sixty minutes, and finally the minute into sixty seconds. They were wise old mathematicians, these Babylonian and Chaldean priests who lived four thousand, three thousand, two thousand years before the coming of Christ. It was not by chance that they hit on these figures of twelve and twenty-four and sixty. No number smaller than sixty can be divided into so many other numbers as sixty. If you look at your clock or watch, you can see how simple it is to divide its face into five-minute periods, and also into quarter-hours and half-hours. We owe a great deal to these ancient *magi*, who gave us our time-scheme in twelves.

These priests kept much of their learning to themselves, for they liked to be regarded as a very learned body, skilled in deep, dark mysteries. To them the common people came to have their fortunes told and their lives predicted according to the lore of the stars.

But some of their learning did reach to the common people for their convenience in time-telling. The sundials were marked on the twelve-hour scheme. But the very thing that the priests had noticed as to the movements of the sun made trouble here. The yearly motion of the sun, as it went north and then south, made the swing of the shadow change from day to day. So the sundials were sometimes behind and sometimes ahead in their shadow pointing.

Berosus, a Babylonian priest of Baal, living about the year 250 B.C., came to the rescue here and hit on a clever way to get round this trouble, caused by the north and south movements of the sun. He made his dial hollow like the inside of a bowl so that it would reflect accurately the movement of the sun in the great upside-down bowl of the sky. His pointer was put above this with a little round ball on the end, and the time was marked by the shadow of this ball. A vertical pointer, standing upright like a tree, would not have worked; but with this horizontal pointer reaching out over the bowl he was able to get the result he wanted. However the sun moved, the shadow moved in the bowl just as the sun appeared to move in the arching sky. By an ingenious set of lines of longitude drawn across the bowl, he got a dial or 'hemicycle' (half circle) which kept time fairly accurately all the year round. The hemicycles of Berosus were used all through the ancient world. Cicero had such a hemicycle nearly

two hundred years later. Hemicycles of Berosus were found in the ruins of Pompeii. The old Chaldean had made an instrument by which his knowledge became of use to the people of his own and later generations in the practical business of time-telling.

Sundials of one kind and another were the most common timepieces all through the Middle Ages, and have lasted to our own day. '*Gnomons*' they were sometimes called, from the Greek name for the pointer giving the shadow, which was counted almost as a person, "the one who knows." But the trouble with the gnomon was that it did not always know. "I count but sunny hours," reads the inscription on an ancient dial. On rainy days or in dull seasons, and at night, the sundial was of no more use than any other piece of metal. The gnomon was the servant of its master the sun. When the sun disappeared how was a man to time his life and keep his appointments? The gnomon could not answer, but the 'water-thief' could.

THE WATER-THIEF

The first part of this story, which goes beyond the beginnings of recorded history, might be told in Babylon or ancient Egypt as well as in India or China. Let us have it as a Chinese scholar of the old school might tell it.

"There was once a learned judge who was never

idle. All day he sat in judgment in the market-place of his village, hearing and settling wisely the complaints and quarrels of the people. When evening came he occupied himself with the things for which he cared, with music and the study of the ancient books, or visiting his family and friends. But the people followed him even to his house and waited in the courtyard until he came out to them. He could hardly finish his evening meal before he was summoned by his neighbours and visitors.

"'How can I have any life of my own?' he said to himself. 'It is not good for a man to eat in haste and never rest or meditate on the words of the ancient sages. I must tell the people when I can see them and when I cannot.'

"In the daytime the people kept time by the place where the sun stood in the heavens or by the length of their own shadows. The judge could say to them, 'Come to me when the sun stands directly above your heads,' or 'Come when your shadow is as long as you are.' But in the evenings or on rainy days there seemed to be no way to tell them.

"One evening when he had been away all day and returned home very late, he found a company of farmers waiting to settle a dispute over some land. The judge must have his evening meal and rest before he could see them and hear their long stories.

"There stood in the corner of the courtyard a little Chinese garden of green things growing, and

on a shelf above it a clever servant had placed a jar with a little hole in the bottom, so that the water from it would come slowly on the plants instead of being poured on them all at once. There was a little trough to carry the water from the hole, so that it was as if a tiny brook were running through this garden.

"As the judge stood welcoming the farmers, a servant came out to fill the jar. Seeing him do it, the judge said to the men, 'See, I will come out to you when two jars have run out,' for he knew that the servant kept watch when he was watering the garden and filled the jar as fast as it became empty. The men, who had been disappointed when the judge would not see them at once, sat down in the courtyard, ready to watch and wait patiently as the water ran in a tiny trickle from the jar. Meanwhile the judge ordered his servant to tell him when he went to fill the jar for the third time.

"When the men had gone and the judge sat at rest in the courtyard, he looked at the water-jar and said to himself: 'Why not have more jars to keep time for me? They would mark the time on rainy days and at night.'

"So the judge set up both at home and in the courtyard by the market-place water-jars with holes in them, which kept time for him and for those who came to him. And before long other people began to keep time by water-jars, so that they became known all over China, and may be

seen even to this day in some of the ancient cities of the old Chinese Empire."

So the story might be told in China. Jars with dripping water were used there as time-measures in 3000 B.C. and possibly as far back as 4000 B.C.

In India a copper bowl with a small hole in the bottom was floated on water in a larger vessel. When the water had pushed up through the hole so that the bowl was partly filled, the bowl would sink to the bottom of the vessel. A watching servant would lift the bowl, empty it, strike on it with a clapper or stick, thus marking for the household that an hour or half-hour or whatever the period of time might be had passed, and then float it again on the surface of the water.

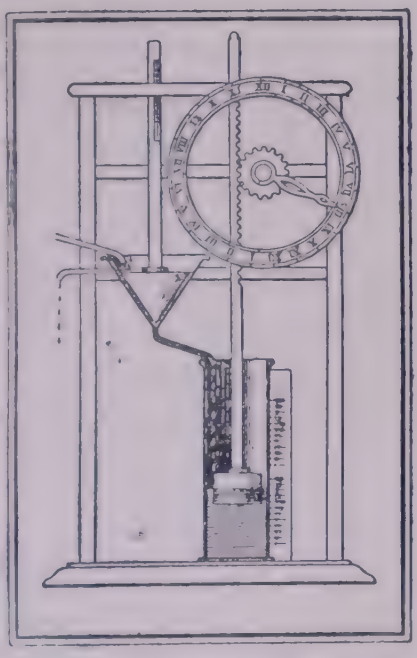
The Babylonians and the Egyptians used water-clocks. Finding that water ran out faster when a jar was full, owing to the weight of the water, they put two jars together. The upper vessel had water always flowing into it through a pipe. It had also an overflow pipe by which water ran out if it reached more than a certain height. In this way the weight of water in this vessel could be kept fairly uniform. With the weight of water the same, it would drip from a hole in the bottom at a regular rate into a second and larger vessel placed below. In this second vessel there was a float with a pointer. This float would rise regularly and so could be used as a time-guide, as we use the hand of a clock.

The interesting thing about these water-clocks,

even the simplest of them, is that they actually measured time. The sundial was a device for reckoning time by the sun. The sun really gave the time for the dial. At a time which we nowadays call ten o'clock in the morning the shadow on the sundial would always stand at a certain mark, which became the mark for ten o'clock. The water-clock measured the hours as a modern clock does, by the length of time covered. It kept time by having a regular interval between the moment of its being filled and the moment of its becoming empty. It *could* be timed by the sun, so that one might know how many hours it took for the water to run out. But in its plan it was simply a time-measure. Fill it at ten o'clock and it would run for six hours and so tell you when the hour of four o'clock arrived. Fill it at twelve and it would tell you by the dripping of its last drops when six o'clock came. If the vessel of water was very large and the hole very small, it might take the twenty-four hours for the water to run out. It was new and different from the sundial in that it worked by the law of dripping water, independently of any other body. In this it was like a machine.

At first it was not a self-running machine. Some one had to pour in the water. Then came the *clepsydra*, or as the two Greek words which make up that name are translated, the water-thief, and that was a self-running time-keeping machine, the first in the world's history.

They say Ctesibus of Alexandria was the first to put wheels into the water-clock. In so doing he added another chapter to the "romance of the wheel" and also made the clock run by itself. Here was a float with a pointer the rise of which was controlled by water. Ctesibus fastened a cord to the float, ran the cord over a pulley and let the cord turn a wheel. The rising of the water supplied the motive power to keep it going, just as the flowing of water keeps water-wheels turning in a stream. If a cogged wheel were kept turning regularly by the rise of the water, a toothed pointer on that wheel could be made to show the time on a clock face, much as the shadow marked it on the face of the dial. The old water-thief really looked a little like our modern clocks. Like them it marked the time, clicking it off by the turns of its wheel, so that to those who stood and watched it turn it seemed to be actually stealing away the time. Sometimes a tiny figure of a man with upraised arm was set as the pointer, that he might be a warning to all



THE CLEPSYDRA OR 'WATER-THIEF'

The first self-running time-keeping machine in the world's history.

who saw him moving round the circle of the clock-face. As he moved time was passing, slipping away into eternity.

Clepsydras were used throughout the Roman world. They were expensive. If they were to keep time accurately their machinery had to be made very carefully and constantly kept in order. But for public buildings and squares and for rich private homes they were most useful. Pompey the Great, the Roman general who lived from 106 to 48 B.C., had these clocks put in the courts where the lawyers were given to endless speech making, "to stop their babblings." He may have taken the idea from the Athenian courts of justice where the water-thief was also used to limit the length of pleas. "The first water," says an ancient writer, Æschines, "was given to the accuser, the second to the accused, and the third to the judges." A special court official was charged with the duty of watching the clock and giving notice to the speakers.

The water-clock had certain faults due to the very fact that it was run by water. In the north of Europe it was likely to freeze in winter. Then, when the prolonged dripping had enlarged the hole, the water fell through too fast. The hole was finally plated with gold, which lasted fairly long. Again, if the water was not perfectly pure dirt gathered round the hole and made the stream run more slowly.

Father Time did away with these difficulties in

his hour-glass, where sand ran from one funnel-shaped bowl into another through a tiny hole not unlike those in water-jars. Hour-glasses were used as far back in history as water-jars, and remained in use until recent times. Indeed, egg-timing glasses which run one, two, or three minutes, made on the model of the larger hour-glass, may be bought to-day.

The hour-glass had to be transparent, for one must see the sand flowing; but glass was made by the Egyptians early in their history. A sand-glass had many things to recommend it. It was cheap, which the water-clock was not. It would not freeze or overflow. It did not need refilling. It could be carried about, as Father Time carries his, although it was clumsy for that purpose. Athenians, however, used these glasses as we use watches.

One of the most interesting later uses of the sand-glass was in the British Navy less than a hundred years ago. Large glasses were used to time the duration of sea-fights, so that in the old log-books you will see a battle recorded as having lasted for three, four, or five 'glasses.' A smaller glass was also used, which would run out in twenty-eight seconds. When it was desired to find the speed at which a vessel was going a log line was thrown out at the rear in which knots had been tied at regular intervals of forty-seven feet and three inches. This number of feet and inches would go in a nautical mile as many times as twenty-eight seconds would

go in an hour. So the line was allowed to run out, with one sailor watching for the knots to appear while another sailor watched the twenty-eight-second glass. By counting how fast the knots appeared, they could reckon how many 'knots,' or nautical miles an hour, the vessel was making. Distance at sea is still calculated by knots, a system which goes back to the rope with knots tied in it and the tiny sand-glass for a time-measure.

While the sand-glass was convenient and cheap, it had the disadvantage of being so bulky and heavy that it could measure time only for short periods. It served its purpose well, but it never really competed with the water-thief.

GALILEO AND THE PENDULUM

Our next clock story swings us over a thousand and more years, out of ancient and classic times into the more familiar Middle Ages. The darkest period of the Dark Ages, following the fall of the Roman Empire, has passed. The incoming of barbarians from the north is centuries past. The Crusades are long over. King John has granted his Magna Charta; Marco Polo has rediscovered the mysterious lands of Cathay and the Orient, of which knowledge had almost disappeared in the Dark Ages; and Columbus has found a new continent in his search for a passage to these ancient lands. Printing has been invented, and the new birth

of learning and art and science is coming all over Europe.

Such learning as there is has been treasured all these years in the monasteries of the Church. While battles were raging, and the Goths and Vandals were threatening to sweep over Europe, amid all the turmoil and the ignorance of the Dark Ages, patient, scholarly monks had tried to keep the torch of learning flickering in their retreats. It is probably to these monks that we owe the special interest in clocks from A.D. 1200 onward. The very name 'clock' comes from the French word for bell, *cloche*, and suggests to us the frequent bells ringing out in the monastery to call the monks to prayers. Alfred the Great had invented the candle-clock, in which a candle on which he made circular lines burned slowly to mark the hours, because he had made a vow to give eight hours out of each twenty-four to acts of religion, eight hours to rest and recreation, and eight hours to public affairs. If the monks were to lead a regular life, they had to have some kind of timepiece to mark the hours. Gerbert the Monk, who afterward became Pope Sylvester the Second, is credited in the ninth century with having made some kind of device with weights and wheels which seemed to the authorities to be so likely to indicate a knowledge of magic and therefore an alliance with the Evil One, that they banished him from France for a time.

By the thirteenth century real clocks began to be

made here and there; some of them are to be seen to-day in museums or on old cathedral-towers. A famous one by Henry De Vick, which was set up in Paris in 1364, was run by shifting weights on a balance. On this clock the signal for the massacre of St Bartholomew was struck. The great change in clock-making which marks the beginning of clocks not unlike those of our own day comes near the end of the sixteenth century, in the time of Queen Elizabeth, of Shakespeare, of Drake, and of Sir Walter Raleigh. This change began with a great moment in the life of that distinguished astronomer, inventor, and scientist, Galileo, who lived from 1564 to 1642, and changed the thought of the world in many ways.

Galileo was an Italian, born in Pisa, and early fascinated by studies into the laws of the world. He was to make the first thermometer. It is said that he was the first to turn the telescope on the heavens and make by its means certain revolutionary discoveries. He was counted mad by the people of his day when he taught in the schools that the sun was the centre of the universe and the earth moved about it. By dropping balls of different weights from the Leaning Tower of Pisa, he discovered the laws of falling bodies. Of all the discoveries that he made none was more interesting in its practical use than the one he made when he was a boy of seventeen and stood in the cathedral watching a swinging lamp.

The lamp, hung by a long chain from the ceiling, swung to and fro as the currents of the air moved it. Sometimes with a strong breeze from the opening of a door it swung through a long sweep. Again it moved but slightly in the air. Others were moving about the cathedral at the moment when the swing of the lamp caught the attention of the lad. Thousands of people had sat and seen those lamps swing. But Galileo was the first to notice that whether the lamp swung through a wide part-circle or through a small one, the swing took just the same length of time. At least he thought it did. So he put his finger on his pulse and counted its beats for a timepiece. It proved as he thought. From the moment when the chain hung straight down to the moment when it came back from its swing, the time was the same, whether it swung through a long arc or a small. Thus was discovered the law of the pendulum, which was to change the whole principle of clock-making.

Galileo did not himself make a pendulum clock, though he did suggest some fifty years later that it might be done. His mind was on other studies. Between 1657 and 1665 Christian Huyghens, a celebrated Dutch astronomer, *did* make a pendulum clock, and others soon followed his example.

In order to understand what the pendulum did for the clock, we must see how modern clocks are made. A clock must have motive power to make it run. The old water-clock used water. In the clocks of

the Middle Ages the power came from the dropping of a weight. If you have ever wound a grandfather clock, you know that by winding you lift to the top weights which have been slowly dropping all the week. A clock must have some mechanism, too, for using the power to run the cords: wheels, a pulley, or something of the sort. That is, the power must be harnessed to turn some sort of machinery. It has to have, also, some kind of a clock face or pointer to show the time. The water-clock and even the sundial had that. Last, but not least, it has to have some kind of device to regulate the use of the motive power, so that it will run the machine at an even rate all the time. That is where the old clock-makers had their troubles. The weights ran down too fast or too slowly, or the wheels turned at uneven rates. Here is where the pendulum came in. With its even swing backward and forward, always at the same rate, it could regulate the speed at which the machinery turned and keep the clock going at an even rate.

The next great improvement was to substitute for the heavy weights a closely coiled spring, which would gradually unwind. The unwinding of the spring gave the motive power, which had been supplied earlier by water falling or weights dropping. This made a small clock or a watch possible.

In the year 1714 a number of naval officers and London merchants presented a petition to Parliament, urging the importance of devising some

method by which ships at sea could find their exact longitude. Among the members of the committee then set up to consider the question was the great Sir Isaac Newton, discoverer of the law of gravity. Sir Isaac pointed out that longitude might be determined with the aid of a watch or clock which should keep time exactly; "but," he added, "by reason of the motion of the ship, and the variation of heat and cold, wet and dry, and the difference of gravity in different latitudes, such a watch hath not yet been made." To encourage inventors to tackle this problem the British Government then offered the enormous prize of £20,000 to anyone who could determine longitude within thirty miles. A young Yorkshire carpenter, John Harrison, who had given up carpentering for watch-making, determined to make the attempt. He began by considering the fact that all metals contract with cold and expand with heat, and that a pendulum on a ship's clock would thus be longer in tropical latitudes than in the temperate or frigid zones. Then he took it into account that the effect of these alterations in temperature is not the same upon every kind of metal, that some resist it more than others do. So he made a pendulum like a gridiron of alternate bars of steel and brass so that the two metals should, as it were, pull against each other and keep the clock true. It was a very great moment in the history of science when Harrison's invention was tested aboard H.M.S. *Centurion* in 1735, and proved absolutely accurate,

while the navigating officer of the ship, calculating without its aid, was *ninety miles* 'out' in his reckoning!

With the coming of clocks and watches for every one's use the modern age in which we live really begins. Our whole world is run by timepieces. Schools and factories, trains, shops, and homes are all managed on a system of time-keeping by which every man's life fits closely into other lives. Without clocks and watches the modern world could hardly run. It has been well said, "The Middle Ages made clocks and watches; and clocks and watches make the age in which we live."

A CLOCK TO GO TWO THOUSAND YEARS

Far away in the Middle Ages, when so many wonderful things were being found out, people began to think that they could do anything if they only knew how. Doctors found that certain medicines would work wonderful cures, and began to wonder if there was not a medicine (an 'elixir,' as they called it) which would keep people young or make them live for ever. Alchemists worked in their secret rooms to find out a process that would turn iron or some other common metal into gold, and so make them and their patrons rich.

It is not strange that when people discovered what wonderful things machines would do they should have wanted still more wonderful machines.

Their machines did man's work for him. They were self-running, too, for a time. But if the water-wheel were to be kept at work running the mill, water had to be running in the stream. The clock had to be wound. Every machine needed human aid from time to time, to keep it going. "If we could only make a machine that would go for ever!" the machine-makers said. So all through the Middle Ages we find some worker here or there possessed by the impossible idea that he might start a machine going that would never stop, a perpetual motion machine.

We of the twentieth century, who have learned more of the laws of matter and force and energy, know that we cannot create perpetual motion machines. But we do know that Nature works in very long terms. To us human beings who live for only a short term of years, it seems as if with Nature as with God a thousand years are looked upon as a day in the cycle of the universe. So by harnessing Nature to do our work for us we can make something that will keep in motion long after we are gone.

In our own time radium has been discovered. Radium is a very active element which is continually breaking up within itself, and changing into something else. This sounds a little like the old alchemist's idea that iron could be changed into gold. We are finding out facts that would astonish the alchemist and perhaps make him say, "I told you so; I always knew it could be done." Changes

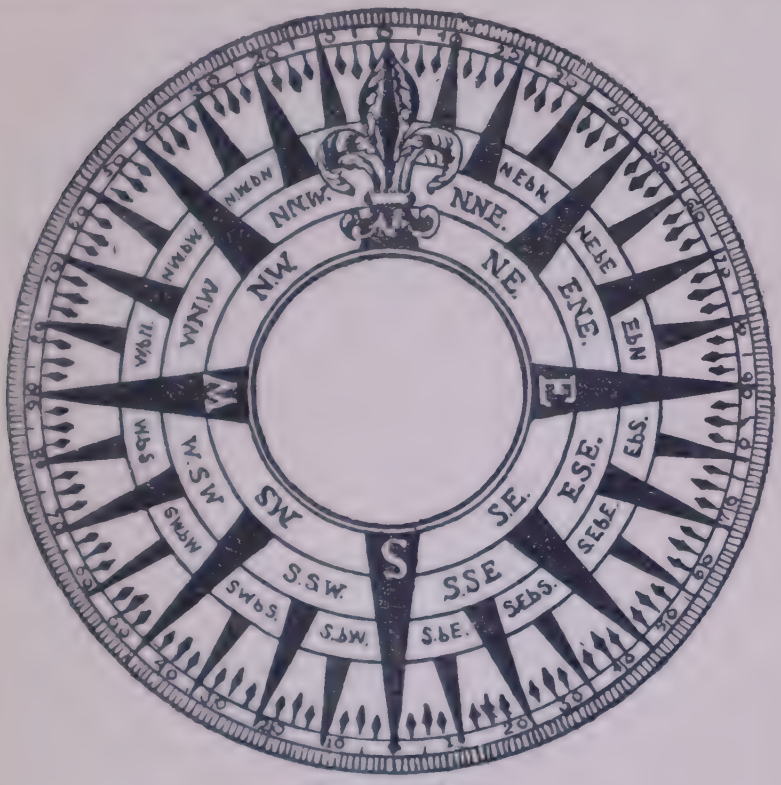
in radium happen very slowly. A radium atom is breaking up, that we know. The scientist thinks it will take a single, tiny atom two thousand years to go wholly to pieces, to change into something else. Now do you see how we are going to make the title of our story come true?

A scientist has made a clock which is run by the action of radium as it breaks up. Radium takes the place of the weights or the coiled spring. The radium atom has been 'wound up' for us by Nature; it is slowly 'unwinding' or going to pieces. Radium in that clock is harnessed to the works. The clock has not had to be wound in all the years since the radium was set in it. Radium holds itself together in somewhat the way in which a coiled spring stays coiled. But the spring unwinds slowly, and the radium breaks up very, very slowly. If the radium keeps on 'unwinding' year by year at the same slow rate, and no accident, like fire or an earthquake, occurs in the place where the clock stands, the clock will go two thousand years. If it stops the trouble will be that man's machinery in the clock has worn out or got disconnected. The radium will not stop doing its part.

COMPASS AND RADIO COMPASS

The Chinese knew early in their history the power of iron touched by a lodestone to point always north and south. Before A.D. 1000, as we know from their

writings, they placed a bar of magnet iron in the arms of a wooden figure on a pivot and the arm of the little man or the spear of iron which he held in his hand would give the direction. In their junks



Compass Card

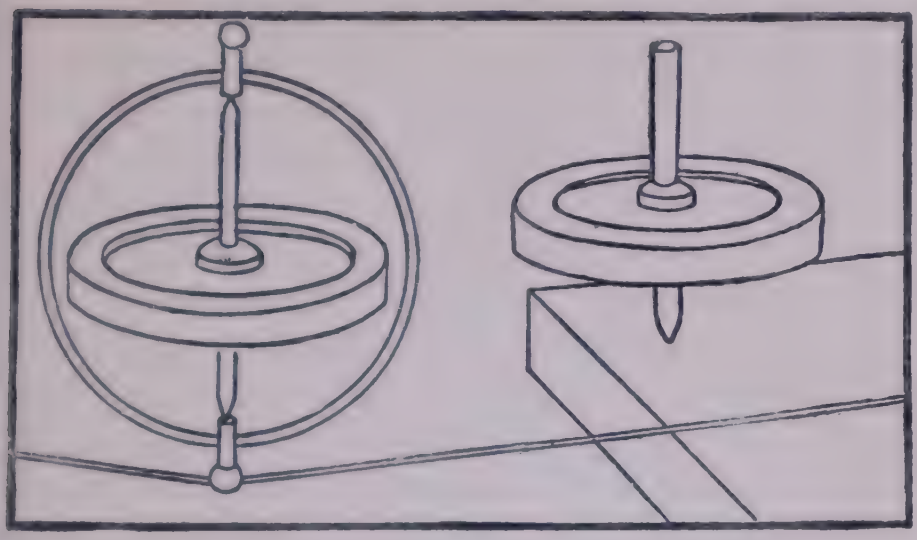
the Chinese mariners of long ago made distant and dangerous voyages to lands as far asunder as Java, India, the Persian Gulf, and the coast of Arabia. From them the Arabs learnt the use of the compass, and the people of Europe probably learned it from the Arabs at the time of the Crusades. An Arabian writer of A.D. 1242 says that "captains who sail the Indian seas use a fish made out of hollow iron

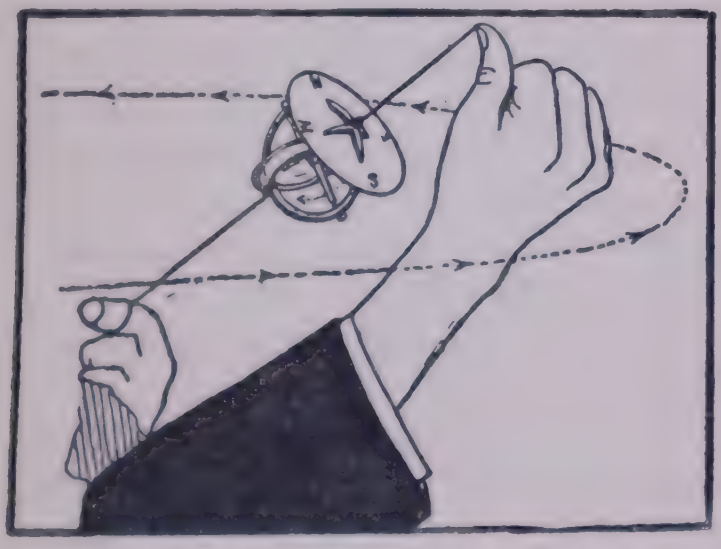
which when thrown into water swims upon the surface and points out north and south with its head and tail." Crusaders in the twelfth and thirteenth centuries referred to the Arabian 'House of the Needle.'

The real mariner's compass with its compass card for navigation was ready for use by 1300 and 1400. Then the age of exploration could begin. With the faithful little needle in its box Vasco da Gama, Columbus, and all the other bold adventurers could start off on their voyages. The compass probably made more change in the world than any other early invention. It almost made a new world.

The hour-glass and the clock gave man a new sense of time and a new control over his use of it. The compass gave him a new sense of direction. As the sun is the natural timekeeper for the world, so the sun, moon, and stars are the natural compasses for the world. By their positions a man can learn to judge not only what time it is but which way he is moving at a given time. But the sun, moon, and stars might be shut out from his sight by a fog for weeks at a time. With the clock he could know the time by day and night. With the compass in his hand he could move freely across trackless waters and barren stretches of desert, sure always of the direction in which he was moving. The little piece of magnetized iron was the best friend the sailor ever won. And the sailor opened up the world for the rest of mankind.

Old-time sailors did not understand the compass even while they used it. We of to-day know that





THE GYRO-COMPASS OR SPINNING COMPASS

the earth is the real magnet, and that its magnetic poles at the north and the south pull the lesser magnets. The mariner's compass has been developed

into a wonderfully fine and accurate instrument. It is still of constant service to mankind.

In our day, while this compass is our mainstay, two new kinds of compass have been introduced. One works on the principle of a top. Watch a top the next time you see one spinning, and you will notice that so long as it keeps going it keeps the same slant. Only when it slows down does it begin to tip and wobble backward and forward. The gyro-compass or the spinning compass takes this law that the axis (a line from the tip to the point) of a top will always point in the same direction if it can, and uses it in a compass. If a spinning compass is pointed to the north star in the morning and keeps on spinning all day, the earth may swing round on its daily circle beneath it and the ship may twist and turn on the waters. That compass will keep on pointing to the north star. On an iron ship a magnet compass has to be watched to see what the pull of the iron in the ship may do in swinging its course out of the true line. The spinning compass cares nothing for iron. It heads faithfully to the north star.

With the coming of wireless man can talk through the air without wires. A ship at sea can speak to a lighthouse on land. A man on a ship, with a radio compass, sends out a question through the dark, foggy night, "Where am I?" He may be fifteen hundred miles from shore. A wireless station in one port sends out its signal. Another station a

hundred or two miles down the shore sends out its signal. By those two reports, coming through the air, the man with his radio compass and his chart of the waters in which he is sailing can draw a triangle on his chart in which those two stations are two points of the triangle and his ship is at the third point. In this way he can determine exactly where he is.

The ways of the sea are always a mystery to the landsman. We look at the sailor's compass and wireless compass, at his charts and other guides, without much understanding of how they tell him what he needs to know. But this we can understand, that to-day man travels on the open sea, on vast spaces of blue water with no guides or landmarks to help him, by as safe and sure a route as if he were walking on land. By the compass he gained his first great victory over space.

FUEL FOR POWER

James Watt and the Steam Engine: George Stephenson and the "Rocket": A Century of Coal

THE First Age of Fire began before the days of Tubal-cain, the metal-worker. It goes back, back, back into the farthest reaches of man's history. The Second Age of Fire began less than two hundred and fifty years ago.

In the First Age of Fire man valued fire for the heat and light it gave. We value and use it for heat and light to-day. In the uses which we make of fire in our homes we are still living in the First Age. We cook by fire; we heat our houses by it. But the First Age has broadened into a Second Age as a tiny stream broadens into a wide river.

Man has always wanted power. At first he had only the power of his own muscles. Then he began to make the simplest kind of machines. In the water-wheel and the windmill he gained power from the rush of falling water and the blowing of the wind. But up to A.D. 1700 and the years immediately following, the work of his world had to be done chiefly by his own muscular strength and the strength of the animals which he harnessed to work for him. It is interesting to notice that we still calculate the output of our engines in terms of

'horse power'; we are not far from the age when the animal was the great source of power and the work which an animal could do was the standard unit of measure.

The Second Age of Fire began when man learned to use the energy given off in the burning of fuel for power to run his machines. The steam engine was the first machine in which fuel was used for power. When fire in the natural process of burning up fuel could be harnessed to turn the wheels of the world, the age of machinery could begin. The Second Age of Fire is the age of machinery, the age in which fuel is used for power.

JAMES WATT AND THE STEAM ENGINE

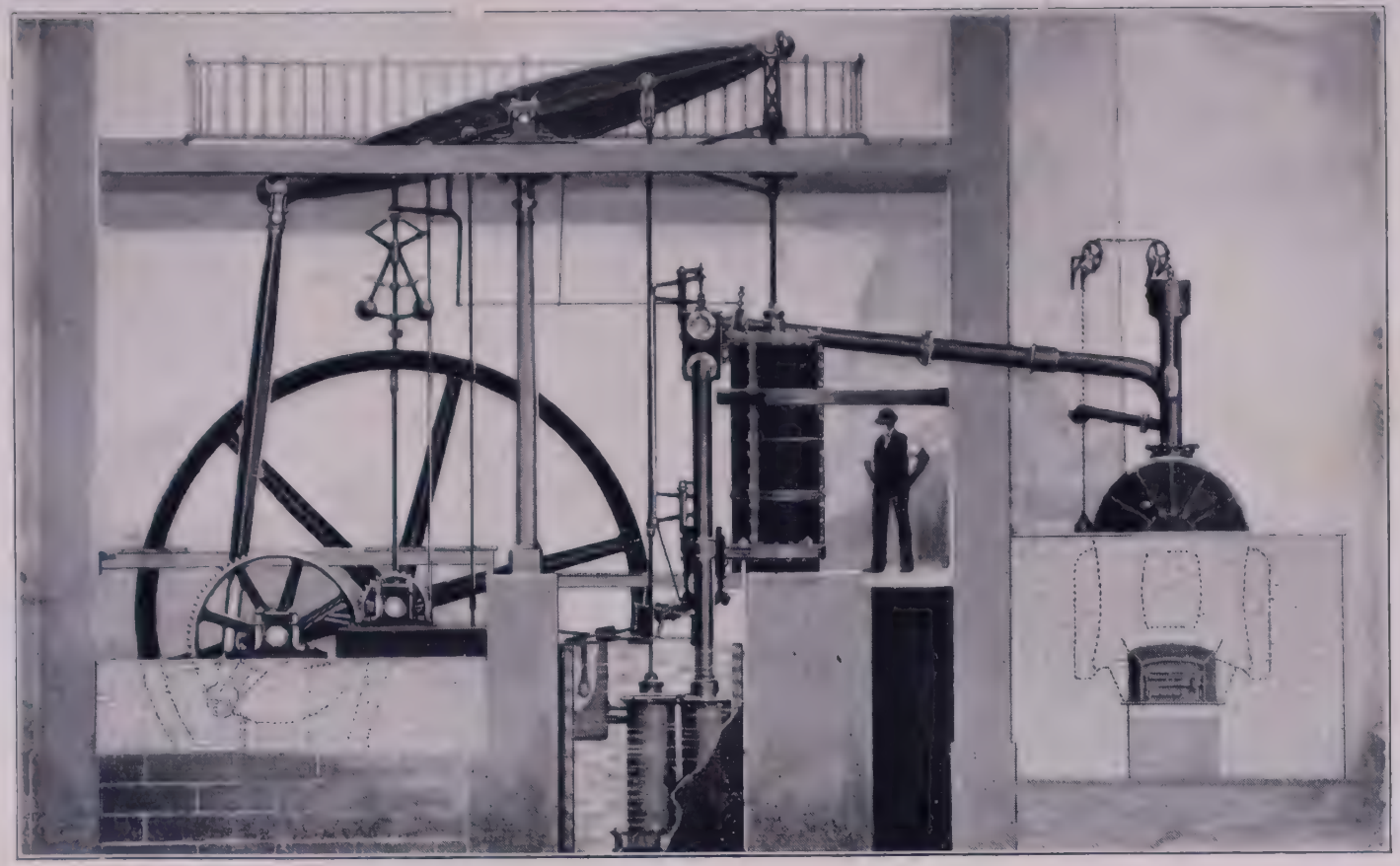
A boy of twelve sat before the fire in the parlour of a little house at Greenock, on the Clyde, with his aunt, Mrs Muirhead. He was a delicate lad, not strong enough to go to school, who had learnt all his lessons at home with his father and mother. 'An idle lad' the neighbours had called him a few years before, when he did not go to school and did not seem to be doing any work. "Why do you let that boy waste his time so?" a neighbour said to Mr Watt, when he called one day and found the child stretched out on the floor and drawing lines upon it with chalk. "Why don't you send him to school where he will learn something useful?" "Look more closely," replied Mr Watt quietly,

"and you may find, sir, that you are mistaken. Examine for yourself and see what my son is about." The neighbour found that the six-year-old was doing a problem in geometry, with the floor for his blackboard.

It was the same feeling of impatience which drove his aunt to sharp speech as they now sat together before the fire.

"James Watt," she said, "I never saw such an idle boy. Take a book and employ yourself usefully. For the last hour you have not spoken one word, but have just taken the lid off that kettle and put it on again, or held a cup or a spoon over the steam at the spout. Aren't you ashamed of spending your time that way?"

It is a homely story, with a sound of truth in it. What practical aunt would fail to grow impatient with a lad who played with the steam from a tea-kettle? Yet the moment when the interest of young James Watt turned toward steam was a moment which was to be remembered by mankind for many, many years after the great inventor had done his work, for before he was thirty-five years old he had changed the clumsy and incomplete steam engine of his day into a practicable steam engine which was capable of doing the work of the world. The discovery and use of fire lifted man above the animals and introduced him to the heritage by which he could conquer the world. The effective use of fuel for power, as it was managed in the



MILL ENGINE DESIGNED BY JAMES WATT

Because a boy of twelve wondered about the steam from a tea-kettle he revolutionized industry.

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steam engine, released him from the toil of a slave and set him on the way to being in very truth a conqueror. The change in the world brought about by the steam engine and its successors makes everything which we can know of James Watt of especial interest to us who live in the modern age of machinery.

Inventors are likely, or were likely in the eighteenth and nineteenth centuries, to have such a hard time in their youth, that it is pleasant to find one brilliant lad who had both comforts and sympathetic encouragement. When James's father saw how the boy liked to handle tools he gave him a set of his own, with which he promptly took to pieces everything on which he could lay hold, and put most of the things together again successfully. He built a small electrical machine which gave out brilliant sparks, to the amazement of neighbouring children and grown-ups as well. He was never strong enough to go to school regularly, but devoted himself, when kept at home by illness, to the study of chemistry and physics. In 1755, when he was nineteen years old, he went to London and worked under an expert builder of delicate mathematical instruments—ships' compasses and chronometers, machines in which any inaccuracies would be serious in their results. Watt probably owed much to the experience gained under this skilful man.

He returned a year later to Glasgow, and intended to set up a modest shop of his own. But trades

were strictly organized under guilds in those days, and Watt had not served the full term required of an apprentice; so he was not allowed to enter the trade. The University of Glasgow came to his aid and allowed him to use one of its rooms, setting up a shop in it for his special use and employing him to take care of its scientific apparatus under the title of 'mathematical instrument-maker to the University.' This was a happy connexion for young Watt, then not quite twenty-one years old, for it brought him into touch with men who could understand his work and be of assistance to him later.

To Watt was brought one day a classroom model of one of the steam engines then in use for pumping water from mines. This, the first really practicable engine employed in commercial work, was a machine invented by Thomas Newcomen, a Devonshire blacksmith, and Thomas Savery, who in partnership had taken out patents and installed their first engine for commercial work in 1711. This engine made use of the expansive power of steam to raise a piston against the pressure of the atmosphere; at the top of the stroke a spray of water was admitted into the cylinder, immediately condensing the steam, so that the piston was borne down again by the pressure of the air (which is 15 lb. to the square inch), and performed useful work in raising the water from the mine. This engine had proved infinitely better than hand-power to run a

pump steadily, but it was far from perfect, and indeed was not a steam engine as we understand the term to-day, but an 'atmospheric' engine, *i.e.*, it was the pressure of the atmosphere which did the actual work.

Watt repaired the engine, as any clever machine worker could have done. But he went beyond that. He used his mind on it. He set the model engine going after he had repaired it, putting water in the boiler. The engine worked as it should; but Watt noticed how wasteful it was of fuel and water, for the steam was used up as fast as the boiler could supply it.

Watt had hit on the gravest defect of this type of engine. At each down-stroke of the piston the cylinder was chilled by a spray of water, so that when fresh steam was admitted it had to condense in sufficient quantity to warm up the cylinder to the temperature of boiling water before it could expand and raise the piston again to the top of its stroke. More steam was used up in warming the cylinder than in doing useful work. If the cylinder could be kept hot, thought Watt, the steam would not be repeatedly wasted in this way. But how could the cylinder be kept hot? On this problem Watt pondered many days. At last, one day as he was walking in the University grounds, the idea came to him. Why should not he make a separate condenser in which the steam would be condensed outside the cylinder, and connect the two with a short

pipe? He set to work at once on the idea, and made a model which worked successfully. The separate condenser was the first great Watt contribution to the steam engine. Some say it was his greatest contribution; but others which followed it, while more technical and difficult to describe, were not less useful. He made improvement after improvement, until in 1769 he took out patents on a machine which was the first real steam engine, that is to say, an engine in which steam instead of the weight of outer air did the actual work of pushing down the piston in the cylinder, and in which all the other absolutely necessary features of his later models were included.

When the steam engine became more than a pumping machine, when it became a machine which could turn the wheels of industry, the modern age in which we live began. "No single man in history did so much to change civilization. With him began the modern industrial era, the era of the factory, the era of machine-made conveniences. Because of his engine Watt must be regarded as one of the world's greatest figures."

GEORGE STEPHENSON AND THE "ROCKET"

James Watt had made a steam engine that would do the work demanded of it. A colliery boy, George Stephenson, rose from a job as driver of a horse in a mine to tending a Watt pumping engine. So

fascinated was he with all that had to do with engines and their ways that he went to evening school in his native village so that he might learn to read the books that explained their working. At eighteen years of age Stephenson was learning his letters; thirty years later he was outstripping all competitors in a contest for a successful steam locomotive which "must be able to draw, day by day, twenty tons' weight . . . at ten miles an hour." This was the forerunner of the modern locomotive.

When James Watt had perfected the steam engine so that it was capable of doing heavy and sustained work, it was inevitable that far-sighted men should see that this engine would not always stay cooped up in coal mines but would replace horse power in hauling loads from one place to another. There had been rude tracks in England, leading from coal mines to ports, since the sixteenth century. Coal carts were heavy and ruts deep; so the workmen laid planks at the bottom of the ruts and found that the wagons moved more easily. To hold the planks at an even width they laid crosspieces, or 'ties' as we call them, across the road. Wooden planks wore out; so strips of iron were put on the planks. The iron strips wore out the wooden wheels of the wagons, and by the eighteenth century iron wheels were in use. The wheels slipped off the edge of the plank or rail, and William Jessop invented in 1789 a wheel with a rim (or flange) on the inside, to keep it from

slipping off the track. So the tracks were ready for the steam engine. But through all these changes the wagons or coal carts were still drawn by horses.

Stephenson was not the first man to put a steam engine into a wagon. William Murdoch, the son of an Ayrshire millwright, built a small steam-driven road-locomotive in 1784, and amazed the country folk of Cornwall when he sent it careering madly along the Cornish lanes. In 1803, Richard Trevithick, a Cornishman, ran a steam-propelled carriage in London, from Leather Lane to Paddington by way of Oxford Street, to the no small astonishment of the Londoners of the time. Then came Sir Goldsworthy Gurney, whose steam-carriages plied between London and Bath, Cheltenham and Gloucester (1823–29), despite the restrictions imposed by the out-of-date laws of the land, and the angry opposition of the proprietors of the old stage-coaches drawn by horses. They were very queer-looking objects, these carriages of Sir Goldsworthy Gurney's. When one of them came to a hill it unfolded a set of movable legs, something like the legs of a crab, to help it to make the ascent!

Then came George Stephenson, born in great poverty, never sent to school as a boy, but of great inventive genius, and fascinated by the pumping engine which he was allowed at the age of seventeen to tend. When he had learned to read he

studied engines until he was finally allowed to build one for the colliery. It was used between the mine and a shipping port nine miles away, and drew eight loaded wagons weighing thirty tons up a slight grade.

Horse power was still cheaper than steam, but in 1821 when Stephenson became engineer for a new railway thirty-eight miles long, he persuaded the owners to make use of steam locomotives. It must have been a proud day in the engineer's life when he drove the first engine over this road, hauling a goods train of thirty-four tiny wagons, the whole weighing ninety tons. To the modern mind the glory of the moment would be somewhat dimmed by the fact that daily a man on horseback rode ahead of the train to make sure that the way was safe and open, though it is said that where the grade was easiest he sometimes had to gallop for a few moments at a rate of fifteen miles an hour to avoid being overtaken.

Wise men saw by this time that steam was to be the motive power of transport in the future. But there were many difficulties in the way. Engines were expensive to operate. The stage-coach lines and the canal companies opposed the granting of any licenses for steam railways. Landowners objected to having the noisy, puffing, smoking machines driven across their estates. In view of all the opposition, it is a wonder that any headway was made. But Stephenson, who was unwearying

in his advocacy for the steam engine, was engaged to build the Liverpool and Manchester line, the most ambitious railway to be constructed at that time. It was at first intended to use as motive power the faithful and dependable horse, or, if not always the horse, a car with some sort of cable connexion which would haul it along. But Stephenson was so persistent that the directors of the road finally offered a prize of £500 for an engine with a specified list of requirements that seemed to many impossible to meet. Stephenson, undaunted, went to work, with his son Robert, on the *Rocket*.

On the day of the contest, October 7, 1829, four engines were presented for the trial, the *Novelty*, the *Sanspareil*, the *Perseverance*, and the *Rocket*. Even before the judges arrived on the scene the bellows in the *Novelty* gave out, so that it was unable to complete. A defect was found in the boilers of the *Sanspareil*, which would require time to repair. So the contest was postponed.

The crowd of spectators which had gathered for the show was so disappointed that Stephenson brought out the *Rocket*, attached it to a coach containing thirty-six persons, and ran them along at the surprising and alarming rate of from twenty-six to thirty miles an hour. Their amazement and admiration were unbounded, and there was little surprise when at the later official trials the *Rocket* came off victorious with the £500 prize.

It has been said of the *Novelty* that according to

its pictures it must have looked like "a milk can set in the rear of a wagon, with a little smoke-stack in front like a dashboard." The *Rocket* was hardly less quaint and impossible from the standpoint of our huge modern locomotives, but it holds its place as their forerunner through several distinct

THE "ROCKET"

achievements in its mechanical construction, which were original with its inventor. As we see it now, in the Science Museum at South Kensington, the *Rocket* is as sombre in colour as it is quaint in form, but in its early days it was gaily painted in white and yellow, and presented a very smart appearance. With the success of George Stephenson and the *Rocket*, the dream of steam power for freight and passenger transportation passed out of the realm of theory and into the everyday world of fact.

A CENTURY OF COAL

Nicholas Allen, a Pennsylvania hunter in the period following the American Revolution, went out one day to hunt. When night fell he was too far up on the mountain to reach home. He built himself a fire on the mountain ledge where he happened to be, cooked and ate his supper, wrapped his blanket about him, and lay down to sleep. A few hours later he was awakened by being uncomfortably warm. It seemed as if the ground on which he lay were warm. When he opened his eyes, instead of the darkness which had been about him when he went to sleep, there was a strong light. Leaping up, he discovered to his astonishment that the mountain seemed on fire all about him. He promptly betook himself to a higher spot where he could lie in safety and watch the smoldering flames. In the morning he went back to examine the place which he had selected for a night's lodging. He had built his fire directly on an outcropping of coal.

Nicholas Allen knew about coal. He was aware that it had been found here and there in Pennsylvania by other hunters. While he himself and all his neighbours burned wood in their fireplaces, it was familiar knowledge to him that there was under the earth in many places solid rock that would burn, and that it could be chipped or mined out and used in place of wood.

Suppose a dweller in China in 1000 B.C., or an

old Roman, or an ancient Briton before the invasion by Julius Cæsar, had waked up to find the ground under him afire! He would not have taken it so calmly. It would have seemed almost as surprising to him for a black rock to burn as it was to Tubal-cain for a rock to melt. Chinese, Romans, and ancient Britons did know about coal. Probably some one in every one of those countries found it out in some such way as Nicholas Allen did. But while it was a curious and interesting fact, it did not greatly matter to them. So long as they could go out, as the early American settlers did, and cut down virgin forests at their very doors, mining coal was too slow and laborious to be worth while.

England is the first country in which coal mining seems to have been taken seriously. In the fifteenth and sixteenth centuries England's forests were running out. There was danger that English fires would go out and English homes be cold unless some other fuel besides wood were used. So England began to dig into the ground for her coal. With only hand and animal labour it was a slow, weary task. In Scotland convicts were made to labour in the Fifeshire mines, in the days of James I and VI. Most of the coal burned in England during Elizabeth's reign, and even later, was brought by sea from Newcastle, and was thence called 'sea-coal.' This is the source of the proverb 'to carry coals to Newcastle.' As the digging went deeper, the coal pits filled with water. Pumps were rigged up, but

they worked so slowly and drew up so little water that they hardly held their own against the incoming water. The first steam engines were used to run the pumps in England's coal mines.

When that coal was being mined the only demand for it was as fuel to give heat to run England's fires. It is strange that this steam engine which was to eat up coal by thousands and millions of tons should be first used in mines where that very coal was being dug.

The great moment in the history of coal came not when it was discovered, not even when it was first burned, but when a machine was made that could convert it into power as it was consumed. The steam engine changed coal from a good, faithful servant, that kept man's fires burning and cooked his food, into a miracle-working giant. When men saw what power they could get from coal in the steam engine they began to think of ways in which they could use that power. They were no longer limited by the work which their own muscles could do, or the work that they could get done by animals or by wind or by water. They invented machines which should set that power to the accomplishing of enormous tasks. Man's whole outlook changed when this giant worker was put at his command. From 1830 to the present so much of the work of the world has been done by machines fed by this useful fuel that this might well be called "The Century of Coal."

MORE STORIES OF TIME AND SPACE

Makers of Picture Words : The First Alphabets : From Papyrus to Paper : The First Printing-presses

AN officer of the French Army was stationed in the year 1799 in a little fortress near Alexandria on the Rosetta river, which is one of the mouths of the river Nile in Egypt. He was interested in the ruins of the ancient civilization of Egypt, which were all about him. He had seen the Sphinx and the Pyramids, those mysterious structures erected by men of another age. Here by the Rosetta river he found ruins of ancient temples with stiff, straight carvings of animals and people. On the columns and on loose slabs of stone which had fallen from the buildings and were buried in the mud there were queer markings which looked like writing but which no one was able to read. It fascinated him to look at this writing, which was probably thousands of years old, and to think of the people who wrote it. How little they recked that there would come a day when their temples would be in ruins and their life on earth would be so far forgotten that no one could tell what their records meant !

One day when a trench was being dug he found to his surprise a stone of black slate on which were cut letters he could read. He had studied Greek in school and knew that this was an inscription written in that language. If the black slab had had only Greek letters it would have been like hundreds of others which could be found in Greece and in other regions of the Mediterranean where there had been Greek colonies and cities. But beside the Greek letters there ran an inscription in the same kind of Egyptian characters which were carved on the ruins all about this stone. There were three kinds of writing on the stone: one set of lines in Greek, and the other two sets in characters which, while both unknown, were plainly unlike each other.

Have you ever been in a railway station at a port where people from many lands arrive? If you have you will have seen the same directions written in several languages, and you will have been able to make out from your reading of the English words some of the words in the French or German or Italian lines written below.

This young French officer had his wits about him. As soon as he saw the lines of Greek letters, below the other two inscriptions, he said to himself, "If each line should be recording the same fact in a different language, the Greek letters would give the key to what the other characters meant."

He took great care of the stone and turned it over to the scholars who were puzzling over Egyptian

carvings. In 1802 a French professor called Champollion began to work on the inscriptions, trying to make out with the aid of the Greek key what the Egyptian characters signified. Remember that this scholar did not know a single word of this strange Egyptian tongue, or of the picture-writing which was so different from our modern alphabet writing.

Champollion worked for nearly twenty years at that stone. Other scholars began, worked a year or two, found out the meaning of one or two characters, and gave it up. But Champollion kept steadily on, until finally he learned its secret. In 1823 he announced to the world of scholars that he had found out what fourteen of those signs meant. Twenty years to find out what fourteen signs meant! But in finding out the meanings of those fourteen puzzle signs, he had discovered the principle on which the signs were built up and put together to convey certain meanings. The Rosetta stone was the key which unlocked all the written records of Egypt and made known to the world the history of a people which had lived so many thousands of years earlier that knowledge of them had vanished from the earth.

When you go to the British Museum and look at the Rosetta stone, think how it bridged a gap of five or six thousand years of time! Savage man lived, talked, ate, slept; and the record of his life perished when he and his family and friends died.

The Egyptians wrote their records on the stones, and their names and history are known to us.

As writing bridges time, so it also bridges space. The Greeks sent the news of their battles by runners, who carried the message to every town through which they passed. Homer's poems were repeated from mouth to mouth. To-day they are printed and distributed all over the civilized world. A letter written by you to-day is read in a home hundreds of miles away to-morrow. The arts of writing and printing have given man a notable power over time and space. Let us see how these arts came into being.

MAKERS OF PICTURE WORDS

If an artist wanted to write a story without using any of the letters of the alphabet, he would make pictures for all his words. His story might tell of how a man went out into the forest to hunt wild animals. For 'man' he would draw a picture of a man, a funny little one such as you and I used to draw when we were small children. If he went to the forest by water, the artist would draw a boat with one man in it. The forest he would show by several trees. The animals he met could all be drawn—a lion, a bear, a tiger. If it rained he could draw a picture of the arch of the sky with rain falling. If he wanted to show that it was morning when something happened, he could show the sun rising. For

evening he could show the sun setting. For night he could draw the moon and stars. An artist could tell quite a long story in pictures, if he set himself to it, a story which you or I could puzzle out if we worked at it for a time.

That is the way writing began. Chinese, Egyptians, Indians—all the early peoples of whom we know did picture-writing. At first every one who wanted to make a record drew his own picture to suit himself. Then there came to be standard ways to represent certain things. A lion, an eagle, the sun, rain, the sea, were represented by certain fixed pictures which every one copied and every one understood.

But all words cannot be pictured. Besides, it is a slow and lengthy process to draw a picture for every single word you wish to put down. So there came to be certain accepted ways of shortening the picture-writing. One of the things that helped in the reading of the Rosetta stone was that the name of a king was always put in a square, or oblong, or oval frame made by drawing a line round the signs that expressed it. So the scholars found out that whenever in any Egyptian inscription of a certain period they saw a set of characters with a frame round them, some king or queen was being mentioned there. Since the inscriptions of Egypt were written chiefly by order of the kings to record certain of their doings, it helped very much to be able to distinguish a king's name in this way.

Another way was to use a picture for a word that had the same sound as the picture word. As an English example, when a bee was mentioned a little bee could be drawn to show what was meant. But the same sound 'be' is also a part of the verb 'to be.' How very simple, then, to draw a tiny bee whenever one wanted to say "I will *be* at the temple at sunset"! In the same way a picture of an eye could stand for the word 'I.'

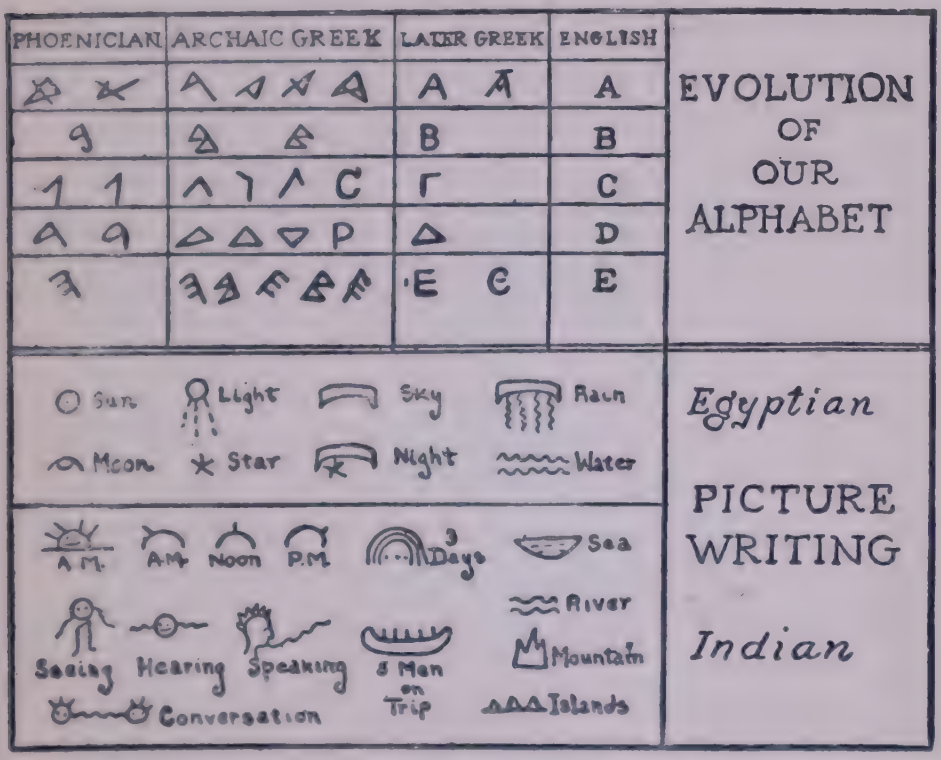
You can see what a chance there was to have all sorts of signs and pictures in this kind of writing. Chinese picture-writing, in our own time, has hundreds and thousands of different signs which stand for almost as many words or ideas.

The simple people could never learn to make all the signs of one of these systems of picture-writings. So there were always scribes or priests, learned men, who devoted their lives to the study of the pictures and to the writing and reading of the picture systems. Do you wonder that it took the French scholar twenty years to find out the meaning of fourteen of these picture signs which were written in an unknown tongue and had drifted far from their ancient shapes, as *real* pictures, into being only signs or symbols which stood to the picture-writers for the whole picture? There is no prettier writing on earth than that done by picture symbols. If it is very primitive, for men simply drew what they saw, it is not too hard to read. But when it gets away from the actual pictures into being a set of

signs that stand for pictures, then it is very hard to decipher.

THE FIRST ALPHABETS

Alphabets started with picture-writing. When little children are learning their letters we give



PICTURE-WRITING AND THE ANCESTORS OF OUR ALPHABET

them alphabet picture books which begin "A for Apple, B for Ball, C for Cow, D for Doll," etc., until all our twenty-six letters have been shown. The Phœnician alphabet, from which our own is derived, might have been read in that way :

A is for Aleph, meaning Ox.
B is for Beth, meaning House.
D is for Daleth, meaning Door.
J is for Jodh, meaning Hand.
K is for Kaph, meaning Palm of the Hand.
M is for Mem, meaning Water.
N is for Nun, meaning Fish.
O is for Oyin, meaning Eye.
P is for Peh, meaning Mouth.

And so one might go on through all the list of characters. Only the left-hand line of letters as they are written here, A, B, D, J, K, is modern. A Phœnician, repeating his alphabet, would say, "*Aleph, Beth, Daleth, Jodh, Kaph,*" meaning "Ox, House, Door, Hand, Palm of the Hand." Think how strange it would be to say those words instead of A, B, C, D, E, as we do!

It was a great moment in man's history when, instead of picture-writing, the idea came to some scribe or group of scribes to break up words into sounds and invent names or signs to represent those sounds. It was a wonderful step forward. At first, as we have seen, words were words and no one had thought of splitting them up. If a word was to be written, it must have a sign all its own which pictured it. 'Water' would be represented by a wavy line; 'going' by a pair of legs walking in one direction; 'returning' by a pair of legs walking in the other direction. Then out of the picture words came the idea of drawing the same picture for words that had the same sound but different

meanings, like the insect 'bee' and the verb 'to be.' The reader could judge from the rest of the story which meaning fitted and made sense. After that they began to put several pictures together to form long words or parts of a verb. Now they came to splitting up words into sounds and making an alphabet which would have letters that stand for those sounds. Since all words are made up of the same sounds, spelling could begin.

Probably the Egyptians were the first to devise some sort of an alphabet. But if they were ahead of the Phœnicians, they were not far ahead. The Egyptians were a comparatively stay-at-home people. The Phœnicians, you remember, were traders who went all over the world in their boats. They carried the idea of an alphabet of separate sounds and letters to the Greeks. The Greeks made up their alphabet, which some of us know, beginning, "*Alpha*, *Beta*, *Gamma*, *Delta*, *Epsilon*, *Zeta*," from which we get our own word 'alphabet.' And at last, out of them all, came by way of the Romans our own simple series of twenty-six letters.

Another great forward movement was the invention of a series of signs representing *numbers*. The form of the numerals which we use to-day we borrowed from the Arabs. The much more clumsy and elaborate form, in which xc stands for 90, lxx for 70, etc., was Roman, and may still be seen on clock-faces and in our prayer-books.

The alphabet would never have become so simple

and easy to read or so universal if it had not been for printing. In printing there is a standard block or letter that stands for 'a,' and no one can re-draw it according to his own fancy, or turn it upside-down, or add a little quirk to it.

But printing is another story!

FROM PAPYRUS TO PAPER

From time to time some one writes a story of a Robinson Crusoe or a Swiss Family Robinson, cast away on a desert island where the heroes have to start life over again with none of the tools or conveniences to which they have been accustomed. They must build houses, make cooking vessels, fashion clothes, set up a sundial or a water-clock for time-telling, and create as nearly as they can the necessaries of life which they have hitherto been able to buy at some shop round the corner. It is interesting to imagine what we should do in such a situation. But even if such a thing did happen to one of us, we should at least know what we wanted. We should also know that it *could* be made. Even if we did not see how to get the desired articles with the few tools and the small skill which we might happen to possess, we should have a very definite picture of them in our minds. That is why a person living in A.D. 1900 can never quite picture the state of mind of the person living in 1900 B.C. The Egyptian or the Babylonian had

never dreamed of the existence of the things we take for granted.

Take this matter of writing as an example. Perhaps it seems odd to you that so many hundreds of years went by before anyone invented a convenient alphabet such as we use to-day. But people did not write in the old days, partly because they had nothing on which to write. It was not until the time of the Crusades that there was any paper in Europe. Even hand-written books of the shape we know, with leaves of paper bound together, did not exist till the Middle Ages. The book of Jesus' time was not a book at all, but a scroll which was unrolled as it was read.

Picture-writing was done on stones. The cave-men drew pictures which remain to this day on the inner walls of their cave homes, where wind and rain would not deface them. On indoor walls pictures and picture-writing could be painted or drawn. On outdoor walls it must be carved in the stone; hence, the many inscriptions like those of the Rosetta stone.

Then one day, a wonderful day, some one took the dried stalks of a plant and wrote a message on that. Perhaps it was a message that had to be sent very quickly and there was nothing else at hand but the dry rushes on which to write it. It may have been written with a stick dipped in water and soot from the fire, or with a mixture of oak-galls and water. A rough message it was, no doubt;

but it could be read by the person to whom it was sent, and that was what mattered. The best plant for such use was the Egyptian papyrus-reed, a marsh plant. People cut it in thin strips, laid these side by side, then laid another line of strips crosswise, and pressed them all down together, with a layer of thin gum between. The writings of Egypt and other countries of the Mediterranean were done on these papyrus sheets, many of which are preserved to this day. "The remembrance of past events depends on papyrus," wrote the Roman historian, Pliny.

Then, so the story goes, a king called Eumenes the Second, who lived from 197 to 158 B.C. in one of the most magnificent cities of ancient days, the city of Pergamum in Asia Minor, wanted to have a library which should rival the famous library of the Ptolemies in Alexandria. Pergamum was already famous for its manufacture of tapestries and pottery and precious ointments. Eumenes wished it to be famous for its books. But he was not on good terms with his neighbour-kings in Egypt, the ruling house of the Ptolemies. There had been strife between the two armies, and the King of Egypt, hearing of his neighbour's ambition to create a fine library, chose a very simple way to stop him. He forbade the makers of papyrus rolls to sell any of them outside Egypt, and the merchants and common people to sell even the plants of the papyrus beyond the bounds of their own country. Since the papyrus

plant grew only in Egypt, it seemed as if Eumenes's plans would come to naught.

But there was another material besides papyrus on which writing had been done. The shepherds in the hills, and the merchants, and even some scholars wrote their records on skins. Eumenes set about improving these rough skins so that books could be made from them. The result was parchment, first called *membrana pergamena*, which meant 'skin from Pergamum,' the city where it was manufactured. Eumenes got his library of two hundred thousand volumes or rolls written on parchment, and he made popular the parchment on which books and deeds of land were to be written for a thousand years or more.

Sheepskin, calfskin, parchment, and papyrus were all expensive. Only the most important records or messages could be written on them. Many other devices were used for the exchanges of everyday life. The Greeks carried a wax tablet which could be melted and used again after the first message had been read and erased. Oyster shells and earthenware tablets were used by the Greeks and Romans. Then paper came.

The Arabs, whose territory extended toward the Chinese Empire, occupied in the year A.D. 751 a city called Sanark. The Chinese attacked it but were driven back by the Arab governor. In his pursuit of the retreating army he captured certain Chinese

soldiers who were skilled in the ancient Chinese art of paper-making. They taught the method to their masters. It spread all over the lands ruled by the Arabs. Damascus was the great paper centre. There remain to this day many Arab manuscripts of the ninth century written on paper.

The story of the spread of the art of paper-making is a story of war and conquest. Through these prisoners of war the Arabs learned it from the Chinese. The Arabs and the Moors took it with them when the Moors conquered Spain in the twelfth century. At the time of the second Crusade it was carried into Italy. The first European paper mill, so far as we know, was started in Fabriano, Italy, about A.D. 1150.

The story of paper is the story of the use of fibre taken from plants and trees. The Egyptians used the actual stalks of the papyrus plant, pressing them together. Paper differs from papyrus in that for paper the raw material (the fibre from the plant) is first reduced to pulp and then fashioned into a sheet of paper. The Chinese made, very early in their history, a genuine paper from the inner bark of the mulberry-tree. Our own sheets of paper are made from similar fibres. Until the beginning of the nineteenth century paper was made from the plant pulp or rags in single sheets and by hand. A French inventor made the first machine by which it could be turned out in rolls as an endless web. The processes of paper-making have been perfected

in an almost miraculous manner in our own time. But paper is still made from plant fibre, in the form of rags or wood pulp, as it was made by the ancient Chinese from the pith of the mulberry-tree.

Inventions often go in pairs or in groups. The Chinese and the Arabs set the stage for the invention of printing which was to mark the change from the Middle Ages into modern times. But printing, with the revolution in life and thought which it caused all over the world, could never have come until there was paper on which books could be printed.

THE FIRST PRINTING-PRESSES

"Necessity," says the old proverb, "is the mother of invention." Printing was invented because books were needed. In the fifteenth century, after the Crusades and the Hundred Years War were ended, there came a great revival of learning. In the Dark Ages, after the fall of the Roman Empire, much of the old learning of the Arabians and Egyptians and Babylonians, and even of the Greeks and Romans, had been lost. Now men wearied of constant wars. Scholars came out from the retreats of the monasteries. Painting, sculpture, and literature began to flourish. Universities were founded. Scholars and students desired to know what other learned men were writing and had written in times gone by. They wanted to be able to read the Bible without

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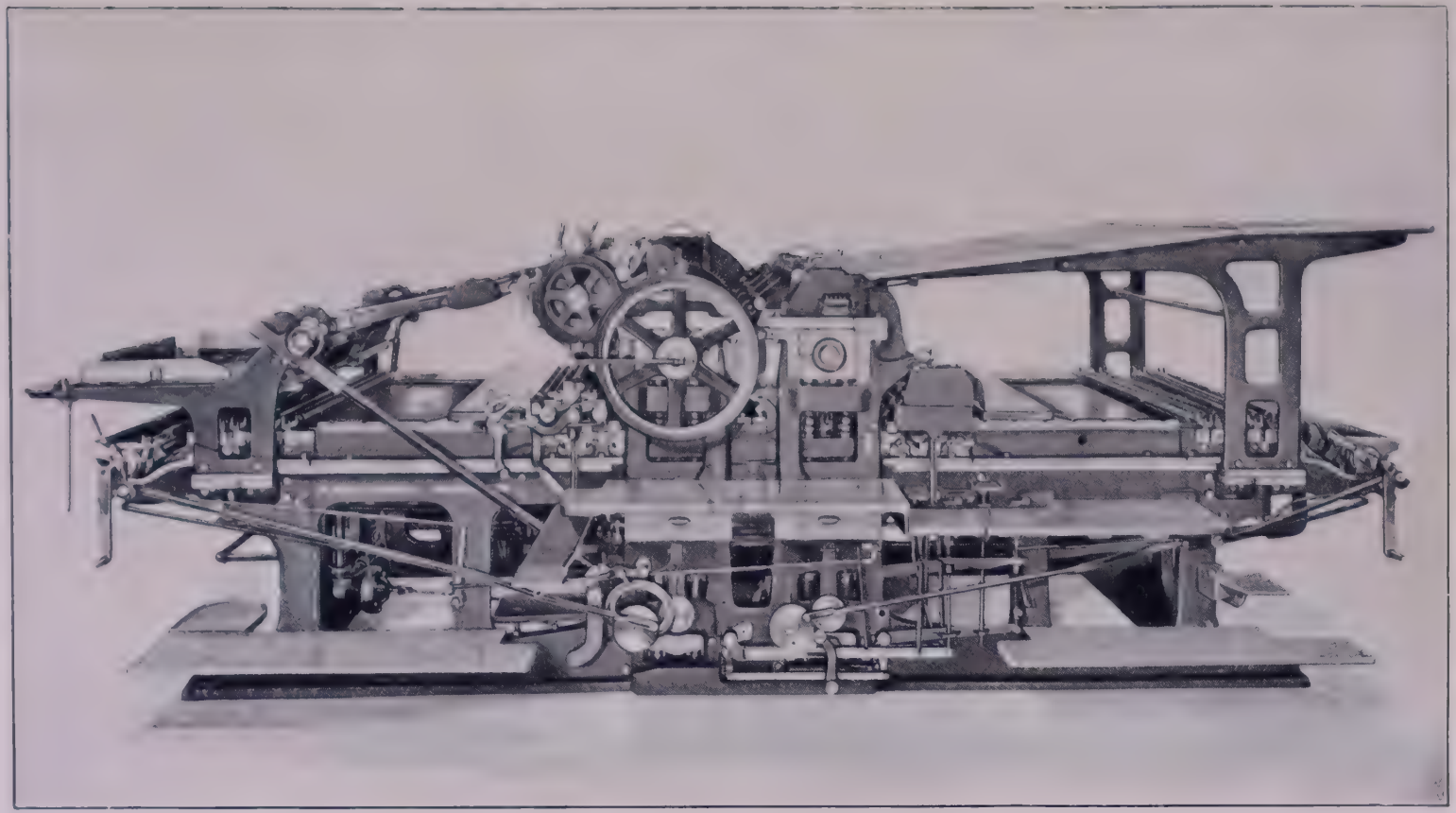
having to go and look at it in a church where the only hand-written copy, the product of years of labour, was so valuable that it had to be chained lest it be stolen. They wanted books. So, as has always happened in the history of the life of man on the earth, when he wanted something very, very much, there were brilliant men of genius who found out a way to get that thing for him. That was the way the invention of printing came about.

The Romans had made type with which to stamp their coins. There had been engraved blocks of wood and steel used for stamping official documents all through the Middle Ages. There had even been a form of printing in the fourteenth century known as 'xylography,' from the Greek words *xylon* meaning 'wood' and *graphein* 'to write.' A wooden block was carved with letters or a picture and smeared with ink. Then a piece of parchment or vellum or paper was pressed on it. By this means 'block books' were made where each page was printed from a single block. These were more likely to be picture books than books with close lines of letters, for pictures were easier to carve in the wood. The first book pictures were called 'woodcuts' because they were made in this way.

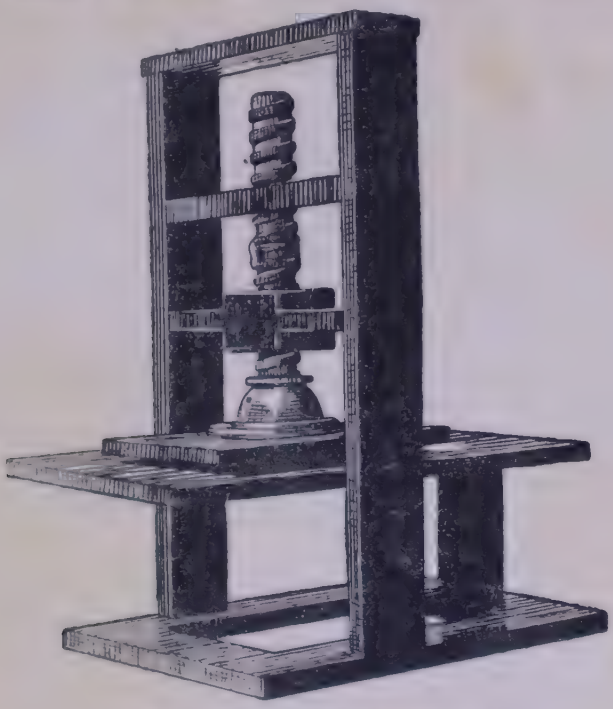
Block printing was a slow and expensive method of producing books, since each separate page had to be hand-carved. But it was quicker than writing each page by hand, since, when a block had been carved, many copies of the page could be quickly



MIEHLE PRINTING-PRESS

This book was printed by such a press. Compare the complicated cogs and wheels with the extreme simplicity of the early press.

printed. Between 1440 and 1450 the idea came to cut up these blocks into tiny blocks or to make tiny blocks with a single letter apiece and set them in racks or frames in the order desired to make words. Thus was the idea of the printing-press



THE FIRST PRINTING-PRESS

A model of the press invented by Gutenburg about 1440.

conceived and carried out. Gutenberg in Germany and Lourens Coster in Holland both printed books from movable types between 1440 and 1450. Coster was a block printer, and the books from his press which have been preserved seem to show that he did part of a page by block printing and part with his new movable type, and that he cut each letter

in wood by hand. Such letters would wear out very quickly. Gutenberg, who is usually considered to have been the inventor of printing, was an engraver. He made beautiful sets of metal letters, copying the shapes of the letters from the kind of writing used by the scribes in copying manuscripts in those days. The first book to be printed was the famous Gutenberg Bible, a wonderful volume of 1282 pages which would be a credit to any craftsman of the twentieth century.

We know very little about Gutenberg. The records of that time are scanty. One of the most interesting written reports of the beginning of printing comes in a French document telling how a king wished to know more about it and probably to set up a rival press after he had discovered the secret. This record tells how on the third of October, 1458, King Charles VII of France, having found that "Sieur Gutenberg, Knight, living at Mayence, Germany, a man dexterous in engraving and in making letter stamps, had brought to light an invention for printing with metal characters," sent his 'Master of the Mint' to Mayence to "inform himself secretly of the invention." This shows that the fame of Gutenberg's movable type printing had spread beyond the limits of Germany before 1458. Within twenty-five years printing centres were set up in all the leading cities of Europe.

To us who know how printing has transformed the world it is interesting to read the words of our

first English printer, William Caxton, placed as a kind of personal letter to his friends at the end of the first volume which he printed. Caxton had been for thirty years governor of a chartered company of English merchants in the domains of the Duke of Burgundy. He had there translated one of the popular French romances of the day, a collection of Trojan legends, which he wished to offer to his friends at home in England. The usual method in such a case was the slow and costly one of having several copies made by hand for circulation among one's friends. But Caxton did differently, though with many apologies, as you will see. The following quotation does not retain the old-style spelling which would make the words hard for a modern reader to understand.

> Thus end I this book, which I have translated, after my author, as nigh as God hath given me cunning, to whom be given the praise. And forasmuch as in the writing of the same, my pen is worn, mine hand weary and not steadfast, mine eyes dimmed with overmuch looking on white paper, and my courage not so prone and ready to labour as it hath been, and that age creepeth on me daily and feebleth all the body, and also because I have promised to diverse gentlemen and to my friends to address [to] them as hastily as I might this said book.
>
> Therefore I have practised and learned at my great charge and dispense [expense] to ordain this said book *in print* after the manner and form as ye may here see, and it is not written in pen and ink as

> other books have been,—to the end that every man may have them *at once*, for all the books of this story, . . . thus imprinted as ye here see, *were begun in one day and also finished in one day.*

This book was printed at Bruges, and so was Caxton's next venture, a treatise on the game of chess. But toward the end of the year 1476 he returned to England, and set up a printing-press within the precincts of Westminster Abbey, at the Sign of the Red Pale (or stake), where King Edward IV used to come sometimes and watch the marvellous new machine at work. The first book actually printed by Caxton in England was the *Dictes and Sayings of the Philosophers*, a collection of maxims translated by Anthony Rivers, Lord Scales, brother of Queen Elizabeth Woodville. The kind of type used is what is known as ' black-letter,' but, though quaint and pleasing to the eyes, it is much less easy to read than modern type.

THE WONDERS OF LIGHT

The First Telescope in Venice: Daguerre and Photographs: Photographing with the X-Ray

AFTER God had created the heaven and the earth, "the earth was without form, and void; and darkness was upon the face of the deep." So runs the Creation story in the Bible. Then "the Spirit of God moved upon the face of the waters. And God said, Let there be light: and there was light."

That was the great beginning. When there was light all else could follow in due course. Plants could grow and flourish. Men and the animals could dwell on an earth where there was light.

The first light which man created for himself came from the fire. In firelight man began his age-long conquest of darkness. In the homes of the cave-dwellers there are niches in the rock where fires were built above the level of the floor to serve as light-givers during the long, dark hours.

One day another means of lighting was discovered. Perhaps a cave-man returned late from the hunt, dressed his meat hastily, and handed it to his wife to cook over the fire. But by the time the meat

was half cooked darkness had fallen. The smoky open fire gave only a feeble light. While the man and the woman and their children were groping about in the shadows, a pool of hot fat, which had dripped from the carcase of the animal as it cooked, suddenly caught fire and blazed up. The whole cave was illuminated. By the light of the burning oil in the hollow of the stone floor the members of the family could see one another and partake in comfort of their food. So long as the hot oil burned there was light.

After that the cave-woman probably kept bear's grease or sheep's fat and heated and lighted it in a hollow shell. One day she, or some descendant of hers, thrust a piece of wood or moss into the burning liquid. It soaked up the fat and burned longer, with less smoke, and more evenly than a separate piece of wood or than the burning oil. That was the first oil lamp with a wick.

Lamps did not change much until modern times. The oil lamps of the days when the Pyramids were built were not unlike those of the cave-dwellers or those used by Cæsar and his Roman cohorts when they marched forth hundreds of years later to conquer the known world. The hollow shell became a metal or earthenware bowl; the wick was of the marsh plant called 'rush,' or of linen threads from the flax plant, or of slow-burning pith; there was a groove or stem for the wick. But the lamps of Egypt, of Greece, and of Rome, as we see them in

museums, are all of the open, oil style with their smoky flickering light.

The Phœnicians discovered for themselves, or learned somewhere in their trading trips, the secret of candle-making. They knew how to dip a slow-burning wick in a mass of hot beeswax and to keep on dipping and cooling, dipping and cooling until they had a rude candle. Their candles date from 400 or 500 B.C. Candles made from the fat of sheep and oxen came later.

But candles and oil lamps were all the means of lighting which the world possessed down to the beginning, or even the middle, of the nineteenth century. The lamps were made very beautiful; the chandeliers to hold candles were of dazzling crystal, which gave back rainbow colours from their flickering light. All kinds of shades and reflectors were introduced. There were short metal lamp chimneys. In America whale oil was substituted for vegetable oils and animal fats. But still, in spite of these minor changes, the flame was produced in the same way and the light was consequently very poor.

The conquest of darkness in our homes and in our streets has come in the train of other great scientific discoveries. The finding of natural gas in the ground and the making of gas from coal started one line of inventions for illumination. Electricity applied to lighting has turned darkness into day in our homes and made our city streets 'White Ways'

by night. By an electric current in a vacuum tube man has been able to separate partially light and heat and to get away from the age-long union between the fire and the light. The successes of modern lighting came in the field of invention. By clever devices man has learned to create small lights for himself which serve him when the great light of the world, the sun, withdraws its brilliance.

The wonders of light are only begun in the story of the conquest of darkness by the creation of artificial lights. Through another set of devices man has learned to make the light of the sun his servant in revealing secrets of the world hidden from his unaided vision. In the telescope, the microscope, the photograph, and the X-ray, he has been aided by light in additional conquests of time and space. Light, with its ally, transparent glass, has opened to him new worlds.

THE FIRST TELESCOPE IN VENICE

Men used spectacles three centuries before the telescope was invented. They found that if they looked through a piece of glass with a slightly curved surface, the objects appeared larger than when looked at with the naked eye or through plain, flat-surfaced window glass which did not bulge out on one side.

Galileo, the brilliant Italian scientist who discovered as a youth the law of the pendulum, knew

about magnifying glasses and lenses and spectacles; but up to a certain time he had apparently never thought of using them for viewing such distant objects as the moon and stars, although his main interest lay for some years in the study of the heavens. The way the idea came to him is interesting.

A Dutch maker of lenses and spectacles, Hans Lippershey by name, had in his shop a curious instrument, put together, as the story goes, by one of his apprentices, with two spectacle glasses so set in a tube that a person looking through it would see the weathercock on a neighbouring church-spire appearing larger than when seen with the naked eye, but upside down. In that shop this toy, which was really the first telescope, might have remained unnoticed save as a curiosity. But the Marquis de Spinola, an Italian nobleman, happened to enter the shop, was interested in it, and bought it. He took it to Prince Maurice of Nassau, who thought of using it in military work when he wanted to spy on enemy territory without risking too close an approach.

Now the story comes to Galileo, where it is told in his own words in the following letter written by him to his brother-in-law.

> You must know, then, that two months ago there was a report spread here that in Flanders some one had presented to Prince Maurice of Nassau a glass manufactured in such a way as to make distant

objects appear very near, so that a man at a distance of two miles could be clearly seen. This seemed to me so marvellous that I began to think about it. As it appeared to me to have a foundation in the Theory of Perspective, I set about contriving how to make it, and at length I found out, and have succeeded so well that the one I have made is far superior to the Dutch telescope. It was reported in Venice that I had made one, and a week since I was commanded to show it to his Serenity [the Doge] and to all the members of the Senate, to their infinite amazement. Many noblemen and senators, though of advanced age, mounted to the top of the highest bell-towers in Venice to spy out ships at sea making sail for the mouth of the harbour, and have seen them clearly, though without my telescope they would have been invisible for more than two hours. For it makes a thing fifty miles off as near and clear as if it were only five.

Galileo's house was the chief attraction in Venice in the days of this new wonder. Morning, noon, and afternoon distinguished visitors, ladies of the court, and scholars came to peer through his tube.

It was a telescope he had made. The day he heard of the Dutch instrument he began to ponder on this new idea, and stayed up all that night experimenting. Finally, he took an old small organ pipe and jammed a spectacle glass that was convex (that is, curving outward) into one end, and another that was concave (curving inward) into the other end. The result magnified three times,

and did not turn the image upside down as the Dutch instrument had.

No discovery ever achieved more instant popularity. Galileo's home was nearly mobbed by the crowds in Venice. The Venetian Senate suggested that they would like a telescope, and when he presented them with one promptly doubled his salary at the University of Padua and made his engagement there a life position.

Galileo was the first to turn the telescope on the heavens. Working with infinite patience and skill he succeeded in making an instrument that would magnify thirty times. The day when he turned it on the heavens marked the beginning of a new age in astronomy.

He first looked at the moon, and was amazed to find there a rough surface with the appearance of mountains and valleys instead of the smooth surface which every one had previously imagined to be there. He was greatly surprised to find so many stars, ten times as many as he had ever seen with his own unaided vision. And to find that the Milky Way which had so puzzled the ancients was made up of stars—that was so incredible that no one believed him when he asserted it!

But Galileo's great moment in the use of his telescope was still to come. That was when he turned his tube on the great planet Jupiter. Galileo lived in the days when the old theory of Aristotle and Ptolemy was still believed, that the earth was

the centre of the universe and that all the planets and stars, as well as the sun, moved round it. To be sure, Copernicus had propounded within sixty years of Galileo's time the true idea that the sun, not the earth, was the centre of our system, and that the earth and the planets revolved round it. But Galileo and some of the new astronomers who had adopted this revolutionary idea were bitterly opposed by the members of the old school, who held to the beliefs of a thousand years and would have none of these new and upsetting ideas. Galileo had got into trouble with these men before. His telescope seemed to restore him to popularity, but its discoveries were to cause him more trouble than anything he had previously done.

On January 7, 1610, one year after he had made his first telescope, examining the planet Jupiter through his instrument he saw three little stars near it. He noted them down, taking their exact positions. The next night he looked again, and Jupiter was on the other side of the three little stars. If the sky with the stars set in their places were moving round the earth, as the old astronomers argued, this was not impossible, except for the astonishing fact that according to their plan the three little stars were on the wrong side of Jupiter. That Galileo could not understand. He waited in a fever of impatience for the next night, but it was cloudy. On January 10 he could see again, and this time there were only two stars and they were

THE 100-INCH TELESCOPE AT MOUNT WILSON OBSERVATORY

Man's vision is enlarged one hundred thousand times when he peers through this gigantic telescope.

on the other side. On the 11th there were two again; on the 12th, three as at first; and on the 13th, four. After that no more appeared.

What Galileo had seen were the four moons of Jupiter, moving round it, as our moon moves round the earth. This he at once realized. It was a wonderful sight to him, for he had been saying for some time that our moon revolved round the earth. But people would not believe it, for they were steadfast in the old theory. Now he could say, "Come, and I will show you with my telescope how another one of the planets, Jupiter, has four moons which swing round it as our moon swings round our earth." He did say so. News of the discovery spread far and wide. But how hard it was for people to believe it! Some said that Galileo had bewitched the telescope. Others refused to look through it. One man said that if he saw the moons of Jupiter himself, he would not believe in them, as their existence was contrary to the principles of common sense!

But Kepler, a fellow astronomer, who was one of the great pioneers in the new science, took the discovery in a very different spirit. He wrote to Galileo:

> I was sitting idle at home thinking of you, most excellent Galileo, and of your letters, when the news was brought to me of the discovery of four planets by the help of the double eyeglass. Wachenfels stopped his carriage at my door to tell me, when

such a fit of wonder seized me at a report which seemed so very absurd (and I was thrown into such agitation at seeing an old dispute between us decided in this way) that between his joy . . . and the laughter of us both, we were hardly capable, he of speaking, or I of listening. . . . But I am so far from disbelieving the existence of the four circumjovial planets that I long for a telescope to anticipate you in discovering two round Mars, . . . six or eight round Saturn, and one each round Mercury and Venus.

With such a spirit of open-mindedness did a really great scientist welcome a discovery which disproved some of his own hard-won ideas about the planets.

A few years later Galileo invented the microscope, which was to reveal the wonders which are hidden from our vision by their minuteness as the wonders of the heavens are beyond our sight because of their vastness. In the very last years of his long life he became blind. He writes then to a friend:

Alas, . . . , this earth, this universe, which I by my marvellous discoveries and clear demonstrations have enlarged a hundred thousand times beyond the belief of the wise men of bygone days, henceforward is for me shrunk into such small space as is filled by my own bodily sensations.

Truly he had enlarged the world beyond all the thinking of earlier ages. By means of the telescopes and microscopes of to-day man has increased

his vision one hundred thousand times beyond the wildest dreams of Galileo himself. All honour to the great pioneer and inventor who in 1610 looked at the heavens through a tiny, home-made telescope!

DAGUERRE AND PHOTOGRAPHS

A photograph is a 'light picture' or a 'light writing.' The name comes from the two Greek words, *phos*, *photos*, meaning 'light,' and *graphein*, the familiar verb 'to write.' We find the same word in 'telegraph,' which means a 'far-off writing' or a 'writing across a distance.' Photography is well-named since light does write the picture on the sensitive film in the camera.

Men knew that light could 'write' or 'paint' pictures long before they knew how to make it take just the pictures man wanted taken and print them on a film which would hold the writing.

A mirage in the desert is a light picture. You have read how travellers will journey many miles toward a green oasis in the desert, which seems always to be just beyond them, only to find that it is an empty reflection of a far more distant scene which has been caught and held by light. A reflection in a mirror is one kind of light picture, though not the kind used in photography.

The ancients, who gave us so many of the names which we use in this story, made and named the first cameras. In Latin, a *camera* is a 'room,' a

camera obscura is a 'dark room.' Perhaps you have seen for yourself the kind of light pictures which can be made by a dark room. If in a room made wholly dark a tiny hole is punched in the curtain covering the window, the sunlight will stream in and 'write' on the wall opposite the window a picture of the house across the street, though that house will appear to be standing on its head.

The Romans probably made dark-room pictures; but the secret was lost for a great many years and discovered again in the Middle Ages. Of all the persons who made discoveries no one ever had a better time with his invention than the Italian philosopher, Battista della Porta, who lived about a hundred years before Columbus. He set up a dark room in his home in Naples to which crowds flocked to see these "pictures painted by light, glowing with colour and marvellously accurate." The pictures appeared on a white wall opposite the hole where the light came in, and showed up quite sharply and distinctly, though they were still upside down. So Porta, who thought that he was the first to find out this secret, had a wonderful time showing his pictures to the crowds which visited him, and then he wrote a book on 'Natural Magic' in which he gave full directions for getting these effects. This book was sold all over Europe, and gave to the camera obscura an immense popularity. A glass ball set in the hole served as a lens and made the pictures clearer; and a dark box with a hole

in it took the place of the dark room. Artists could carry these 'cameras' with them and study the scenes they wished to draw or paint through them, often doing the actual drawing with their aid.

We smile at anyone going into such raptures as the old Italian did over seeing an outdoor scene reflected through a pinhole on a white wall. But Porta and the camera-makers and the lens-makers were getting ready the box and the lens which were to make our modern camera. They had the pictures. What was needed was the right kind of surface on which to catch and hold the images which they were seeing through the lens or throwing on a white wall.

It was two hundred years before the chemists had made ready the materials with which that could be done.

Louis Daguerre worked as a scene painter at certain Paris theatres. He often used the camera obscura to help him in his painting, and about the year 1824 became interested in the idea of trying to 'fix' the image which the camera gave. We can hardly follow him, or the other inventors of that time, through the long maze of experiments with this chemical and that, or with this substance or that on which to 'catch' the picture. One scientist, who was working with microscopes in the study of insects, used leather for his printing surface, and succeeded in getting a faint image of a

flea, 150 times enlarged, on his wife's kid gloves. But naturally his wife did not encourage his further experiments. He finally got results on paper treated with tannin. Another worked with flat paving stones for printing plates, and finally got an image which he held on tin. The story of every one of the pioneers working in this field is fascinating, and credit is due to several French and English inventors. But the thrilling moment came when Daguerre in his laboratory fixed the first imperfect image and exclaimed: "I have caught the light! I have arrested his flight! The sun himself in future shall draw my pictures!"

Daguerre had been experimenting for many years. He had been in partnership with Nièpce, the man who began with paving stones as plates for his images and who finally caught and held an impression on a plate of tin treated with certain chemicals. But Nièpce had died after experimenting for fourteen years, and the process on which both had worked was far from successful.

One day Daguerre laid a silver spoon on a metal which had been treated with iodine. When he picked up the spoon he found that its image was printed on the metal. This showed him that he was doing well to use iodine, and it suggested the idea of a silver plate treated with iodine on which to catch the picture. He put his plate into his camera, but the image was almost too faint to be seen. He was bitterly disappointed.

The plate was of silver and therefore too valuable to destroy, so he laid it away in a cupboard. The next morning he went bravely to work again, in spite of his disappointment. But when he opened the cupboard, what was his surprise to find a fairly clear picture on the silver plate instead of the very faint and shadowy one which he had left there the day before? Some chemical in his cupboard must have accomplished in the night the work of bringing out the faint image of the day before. But what chemical?

Then began a series of days and nights full of excitement for Daguerre. Each day he took out one chemical from the cupboard. If the plate should show up the next morning with a clear image without that chemical in the cabinet, plainly that chemical was not the magical one which was so mysteriously and silently doing the desired work. Finally, there was only one bottle left. That must be the one. Still to make sure Daguerre left a fresh plate in the empty cabinet. The next morning he went as usual, and behold! the plate was developed in spite of the fact that every bottle was gone. Then he was puzzled indeed! But a careful search of the cupboard revealed that a few drops of mercury (the silvery mineral which we see in our thermometers) had spilled on the bottom shelf. Their vapour had been the wonder-worker responsible for bringing out the shadowy and indistinct print on the silver plate.

With that secret revealed well might Daguerre say, "I have caught the light! . . . The sun himself . . . shall draw my pictures!"

On August 10, 1839, the French Academy of Fine Arts met with the French Academy of Sciences to honour Louis Daguerre, the scene-painter of Paris. Throngs of artists and students waited outside in the streets while Arago, the most celebrated scientific man in France at that time, announced to the distinguished company of scholars that Daguerre had successfully produced a permanent photograph. Light had written on silver, and that writing had been preserved.

Daguerreotypes soon became popular everywhere, but how trying it was to sit for one's photograph! One had to sit motionless for twenty minutes in the most brilliant sunlight while the image was slowly etched on the metal plate. A photographer could open his camera, walk to his place in the sitter's chair, remain there for the necessary time, walk back and close the camera, thus taking his own photograph with no effect shown on the plate of his absence from the seat at the moments of the beginning and ending of the operation.

Nevertheless, the instantaneous photograph of to-day, the colour-photograph, the moving picture film, the photographs sent by wire or by radio, and all the rest of the modern wonders, trace their ancestry back to the simple dark box with its glass ball in which men learned to catch and then

to fix on a chemically treated surface the 'light picture.'

PHOTOGRAPHING WITH THE X-RAY

In January, 1896, commenting upon the news that Professor Roentgen at Wurzburg University in Germany had discovered a new kind of light that drove through solids as if they were not there, one of the leading American science journals wrote: "It is yet too soon to indulge in the wild possibilities that have been suggested for this process. When the details reach us, the process will probably prove to be of *scientific* rather than of *practical interest.*" This comment, by the way, was on the same page with two equally cautious articles on the 'horseless carriage.'

Yet so fast does the world move that to us it is a commonplace of everyday life that if the baby swallows a safety-pin or a boy breaks his arm or a dentist wants to find out something about the root of a tooth, the patient is immediately sent to an X-ray operator who will take a photograph that will look through all the outer coverings of skin and flesh and show how things are inside the body. The 'process' has certainly proved to be 'of practical interest' to the most humble and unscientific person. Let us see how this discovery came about.

Light comes to us in waves, striking against the

surfaces which stop it as the waves of the ocean beat against the shore. The eye is a camera which receives and focuses those waves and carries the report of them to the nerves connected with our brains. But just as a wireless set is tuned for certain wave lengths and does not catch others, so the eye is 'tuned' to a certain group of light waves and does not 'see' with the other waves which may strike against it. All this knowledge of a great keyboard of waves coming through the ether of space, which explains electricity and wireless and X-rays and many other curious and interesting things, was hardly known at all in 1895 when Professor Roentgen made his discovery in his laboratory at Wurzburg.

Scientists had begun in the latter part of the nineteenth century to find out about some of these things. In particular they were experimenting with a tube from which the air had been drawn out. When they drove a current of electricity through such a tube strange lights which they did not understand were given out. Roentgen was working with one of those vacuum tubes when he discovered X-rays.

He had covered the tube with a heavy shield of black cardboard, so he knew no ordinary light would come from it. Yet he noticed that on a piece of sensitive, chemically treated paper lying on the bench where he was working a peculiar black line had appeared. Such a line could only come,

according to anything he knew, from exposing the paper to a strong light. Yet where was the light coming from? He had been passing an electric current through the tube. The effect must come from it, in spite of the heavy covering of black cardboard.

That was on the 8th of November, 1895. He began at once to experiment with these new light rays. He could not see them, but they were evidently there, for they acted on sensitive screens, such as the paper where he had noticed the first mark. He put wood and cloth between the tube and the screen. The rays went right through. He tried metals with the same result. Then he put his hand between the tube and the screen, and the outline of the bones showed through the flesh. For the first time in history a man could see his bones through the flesh that covered them. Next he tried to get a photograph of his hand as the bones were shown by these new rays, and found he could do that.

The discovery was announced at the December meeting of a scientific society in the little town of Wurzburg. On January 4, 1896, Doctor Roentgen read a paper describing it to the Berlin Physical Society. Within three or four weeks the news of it had gone all over the world.

'X-rays,' Professor Roentgen called these new rays of light, so unlike anything ever seen before, for 'X' stands for 'unknown.' Although they are

now far better understood than they were in 1895, still it can never cease to be a wonder and a mystery that by their use a man can actually take photographs of objects which he cannot see with his own eyes.

NEW SOURCES OF POWER

Benjamin Franklin and his Kite: The Compass Again: Faraday and the Dynamo: The First Oil-well in America: Engines on Wheels: The First Balloon Flight: Engines on Wings: Linking Continents by Aeroplane

WHEN Matthew Boulton, partner of James Watt in producing and financing the first steam engines, was presented at Court in honour of his services to science, the reigning monarch, George the Third, inquired graciously:

"In what business are you engaged?"

"I am engaged, your Majesty," replied Boulton, "in the production of a commodity which is the desire of kings."

"And what is that? what is that?" demanded the King.

"Power, your Majesty," replied Boulton.

King George himself was shortly to be shorn of much of his own power and glory by the loss of his American colonies. He little thought that the plain mechanic and business man who answered him so quietly was standing at the centre of a circle of power that was to extend from England over the wide world. He could not know that the quaint little boiler that was running pumps in coal mines

was to rule the world in another seventy-five or a hundred years.

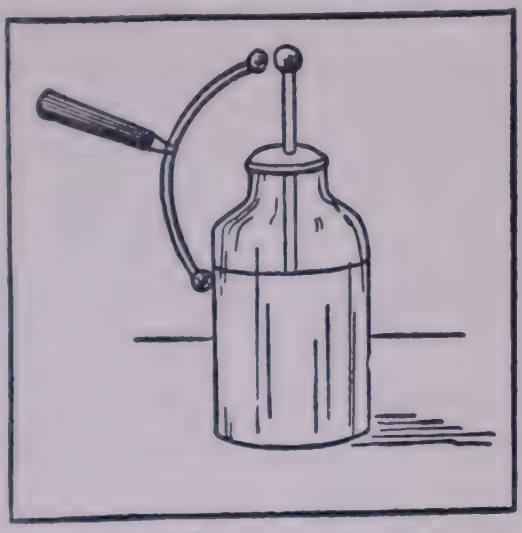
Over in those same colonies which were to give the King so much trouble, a "wise man of the West," one of the master spirits of science as well as of statecraft, was playing with another kind of power which was to change the world. Benjamin Franklin was flying a kite in an attempt to bring the very powers of the air under man's control.

BENJAMIN FRANKLIN AND HIS KITE

"Curiosity," said Plato, "is the mother of all knowledge." Benjamin Franklin was possessed with the divine gift of curiosity. Nothing was too small, nothing too great to interest him. He used the printing-press of his time and left it better than he found it. He invented an open stove that still bears his name. His lightning rods were used all over France and America. Post offices, libraries, schools, savings banks, are all in debt to him for some suggestion or invention that improved them.

Fortunately Franklin lived in the age when electricity was attracting much notice. He had one of the first friction machines in the United States, a queer little affair with a revolving glass globe by which a feeble current of electricity could be started. The Leyden jar was invented in his time, and he was as excited as anyone over this marvellous idea

of 'bottling' the mysterious force of electricity. A French scientist had knocked over a whole company of soldiers whom he had persuaded to clasp hands so that he might get a circuit and send a charge of electricity through them. Franklin promptly experimented and knocked down six men with his six-gallon Leyden jar.



THE LEYDEN JAR

Benjamin Franklin knocked down six men with his six-gallon jar of 'bottled' electricity.

Franklin never left any subject just where he found it. His was the pioneer type of mind that goes ahead into realms of knowledge as yet unexplored. He became convinced that this electricity with which he and his fellow-experimenters were getting astonishing results was identical with the mysterious force in the air which manifested itself in lightning.

There is a famous story, which we should be sorry to lose, that after he had conducted a series of tests that convinced him his theory was right, he went out one June night in the year 1752 and flew a kite in a thunderstorm. This story tells exactly how he fastened a bow of silk with a key tied into it at the end of a kite string, and sent the kite up into the overhanging thundercloud, with the result that

he felt instantly an electric charge in the key in his hand. The friend who wrote the life of Franklin in which this story occurs undoubtedly believed that Franklin did that very thing. Indeed, Franklin described such an experiment as possible in a letter to a friend in England. But historians say that in all his own records there is no statement that he actually did fly his kite *in a thunderstorm*, and scientists tell us that if he had done it the chances are one in ten or even only one in a hundred that he would have lived to tell the tale. A Russian who tried a similar experiment fourteen months later paid for it with his life. So the learned men of our day insist that wise old Benjamin Franklin was altogether too careful and canny to risk his life by attempting anything so rash; and that he proved his point by the much safer and equally important tests of which he left record in his written works. That Franklin flew a kite to make tests of cloud electricity, no one doubts. That he flew a kite in a thunderstorm and held in his hand a key tied to that kite string, many people do doubt. Anyway, if he did, no one of us had better try to repeat the experiment, lest we fail to be the one in one hundred who might escape without a death-dealing shock from that same lightning.

What Franklin did achieve was to prove once and for all that the friction-made electricity which man was creating in his workshops and the electricity of

the clouds were one and the same thing. That was the most remarkable fact which anyone had discovered about electricity in the two thousand years since the Greeks had found that amber rubbed with a cloth drew light objects to it. We make note of that early discovery in the name 'electricity,' which is from the Greek word *electron*, meaning 'amber.' Gilbert, a noted surgeon at Queen Elizabeth's Court and a brilliant student, gave the name in a book which he wrote in A.D. 1600. He had found that twenty other substances so rubbed would give the same effect; so he said that these other substances had been 'amberized,' or 'electrified.'

Franklin made careful studies of the whole theory of electricity. A French scientist had shown in 1733 that there were two kinds; Franklin named them 'positive' and 'negative,' the names by which we know them to-day, thus grasping for the first time the epoch-making idea that electricity under whatever forms it showed itself, whether in one kind of charge or another, whether in the clouds or in man's machines, was one great single force. He even showed that clouds might have negative or positive charges, thus explaining the cause of lightning displays in the heavens.

The great moment in science in which Franklin figures was when with his kite, whether in a thunderstorm or only in cloudy weather, he got an electric charge from the clouds through the key in his hand and proved that the electricity in rubbed amber and

in friction machines was identical with the electricity in the distant clouds.

THE COMPASS AGAIN

When the Arab sailor of early days steered his ship by the compass needle, he knew no reason why that needle should point always to the north. It was enough for him that it did so. Scientists who lived eight hundred years after the compass was first used on the Mediterranean Sea knew little more than did the simple sailors of A.D. 1000 the reason for the needle's action. They had come to call the force that ruled the compass needle 'magnetism'; but they did not understand or explain it.

Then along came Hans Christian Oersted, of Denmark, who was to be called by men of his day the 'Columbus of electricity.' Hans was born in 1777, in a little Danish island town. His father was the village apothecary. There was no village school, but the two older boys, both of whom were to become famous, were sent to an old German wigmaker and his Danish wife to learn to read and write. Their teacher knew arithmetic only through addition and subtraction. Another boy who had been to a better school before he moved to their village showed them how to multiply, and the village pastor, who came often to their father's house, taught them how to divide. Their father taught them everything he could at home, and took

them into his shop when Hans was twelve. Meanwhile a university student came to the village and was promptly besought to give them some hours of work each day. The old wigmaker had taught them German, Danish was their mother-tongue, and the mayor of the town taught them French and English. They borrowed every book in the village, and when Hans was seventeen they went with their father's consent to Copenhagen to take six months of special training before they should try the entrance examinations. Their thirst for learning had served them well. They passed with high marks and entered the University, where they managed to support themselves, with small government scholarships, until both graduated with honours. Anders, who was a year younger than Hans, began as a lawyer; he was to become the most distinguished jurist in Denmark. Hans had been especially interested in medicine, astronomy, and physics, of which he had learned in his father's shop. From the moment of his graduation he devoted himself to science, beginning almost at once to publish brilliant and original papers. In 1806, only seven years after he took his last degree from the University, he was called back to be Professor of Physics.

During all the years of new work with electricity, from 1750 onward, there had been signs of some connection between electricity and magnetism. When houses or ships were struck by lightning, knives and forks were often found to have become magnets.

Lightning affected the direction of a compass needle. A magnet pulled objects to it; so did a charged rod. In other ways the behaviour was similar. But no one had been able to prove that they were related.

Hans Oersted went to work on the idea that there was some close bond between the two. He took electric batteries, such as Volta of Italy had invented in 1799, which produced a steady electric current. Then he took a compass. He knew that the needle of a compass was drawn to the north by magnetism. If an electric current could change the direction of a compass needle, it would prove that the two were in some way related.

He tried all sorts of experiments, with no results. Sometimes the compass needle seemed to be disturbed when electric wires were near it, sometimes not. It is said that Oersted, though a brilliant thinker, was not clever at laboratory experiments. Still he persisted, trying this way and that. One day when he was lecturing to his students in a small private course he put a wire (through which an electric current was flowing) over the compass. As it happened he laid this wire *parallel* to the needle instead of *across* it, as he had done at other times. That made the difference between this and his other experiments. Instantly the needle of the compass swung round until it stood at right angles to the wire. He shut off the current; the needle swung back to its usual direction, pointing to the north. He released

the current again; the needle spun round again. He and his students went wild with joy as they saw that little needle spin. No wonder! Scientists everywhere were trying to accomplish this very thing. Oersted himself had been working at it for thirteen years. Now, by a fortunate combination of the parts of his apparatus, he had done it. Magnetism by its nature kept the compass needle pointed always to the north. But at that moment an electric current was ruling that magnetic needle and proving strong enough to turn it away from the north. Electricity must be, at least, a twin force to magnetism.

Oersted's discovery, announced in 1820, was seized upon with enthusiasm by men of science. "He opened the gates," said Michael Faraday, "of a domain in science dark until then, and filled it with a flood of light." "The electric current was a link," says a writer of our own day, "like the Panama Canal, between two great oceans: electricity and magnetism. These vast realms the electric current joined and converted into one inseparable body."

Within a few years other scientists and inventors turned Oersted's discovery to practical uses. Magnets were made by wrapping wires round pieces of iron and sending a current through them. Ampère, Arago, and Davy became famous for their discoveries. But it all began in that small lecture-room when at the bidding of the apothecary's son a man-made machine for the first time in history

set up a current of force which pulled the compass needle away from the north.

FARADAY AND THE DYNAMO

Michael Faraday was fourteen years younger than Hans Oersted. He was born in 1791 at Newington Butts, on the outskirts of London. His father, a blacksmith, was not a man of robust health, and the family was poor. Yet the parents gave their children what was worth far more than money or education, for they brought them up with the utmost care. Faraday never ceased to be thankful for the happy family circle and the example set there of industry, good habits, and strong religious principles.

Young Faraday learned to read and write and to do simple sums in arithmetic, but that was all the regular training he had, and much of that was given by his parents. At thirteen he had to go to work to help in the support of the family. His earliest job was given him by one of his father's friends, the owner of a bookshop and bindery. This was his first contact with that world of thought and learning, hitherto unknown to him, in which he was destined to win enduring fame.

There were wonderful new science books being printed then, and young Michael read them all. Those on electricity particularly fascinated him. He saved money penny by penny until he could buy

some chemicals. With these, a glass bottle, and some metals and wires he made himself an electrical machine before he was fourteen.

Some years later, but while Michael was still an apprentice learning his trade, he saw in a window an advertisement of a series of lectures on science. He was eager to go, but the entrance fee of one shilling was entirely beyond him. An elder brother, Robert, who was working with his father as a blacksmith, had a little more money. Seeing how eager Michael was to go, Robert came to his rescue and gave him the needed shillings, one by one, for twelve or thirteen lectures. That gave Michael his start. He made friends with older students at the lectures. From that time, as he wrote to a friend, he never swerved in his desire to devote himself "to the service of science." We who live more than a hundred years later may be grateful to that generous brother who gave the needed help.

It was a bold step in those days for one born and bred in one of the 'trades' to venture to leave it for science. The story of how Michael came to do it starts with another set of lectures, given some years later by Sir Humphry Davy, one of the most interesting English scientists of the time. To these Faraday was taken as a guest by a customer of the bindery where he worked. This was a great adventure for the young man, who sat in the gallery and took full notes of all that the famous man said and did. Michael had long had the habit of noting

in his scrapbook everything he learned and making drawings of apparatus used in experiments. He wrote out the notes of these four lectures, with drawings, and bound them for himself in a neat cover. (The book is a treasure kept in the British Museum now.)

A year or more after the lectures had been given, young Faraday grew quite desperate in the trade where he seemed fixed for life and took a bold step to see if he could get out. He sent that little volume to Sir Humphry, asking if there was any chance that he could get work under him. This was in 1812.

Davy consulted a friend called Pepys, who made a note of the fact.

> "Pepys," said Davy, "what am I to do? Here is a letter from a young man named Faraday: he has been attending my lectures and wants me to give him employment at the Royal Institution. What can I do?" "*Do?*" echoed Pepys; "put him to wash bottles: if he is good for anything, he will do it directly; if he refuses, he is good for nothing."

Sir Humphry saw Faraday shortly afterward, and advised him to stick to his trade for a time, telling him that Science was a harsh mistress, rewarding poorly from a money point of view those who devoted themselves to her service. A few months later, however, when young Michael was undressing one night, he was startled to hear a loud knock at

the door and to find a carriage standing before the house. Going downstairs he opened the door to receive from the hand of a footman with a powdered wig a note from Sir Humphry asking him to come to his laboratory in the morning if he still wanted a position.

Faraday began his engagement as assistant at the Royal Institution on March 1, 1813. He was to have twenty-five shillings a week, for assisting lecturers, setting all instruments and apparatus in place for lectures, cleaning all the models and apparatus, and waiting on everybody. The youth who had preceded him had thought the work too hard and had been discharged for neglect of his duties. Faraday did all this work and in addition did private research for Sir Humphry. His first job, if not that of washing bottles, was the unpleasant task of extracting sugar from beetroot; his second, to work with a particularly evil-smelling chemical. For a year he spent most of his time on explosives, and he and his chief were several times injured from the unexpected behaviour of some new compound. Both took all these things for granted in the service of their royal mistress, Science.

It is a remarkable story, this tale of a boy with hardly any regular education, with no money, a blacksmith's son and a bookbinder's apprentice, and of how he fitted himself to become the valued assistant of a great scientist before he was twenty-

two years old. After we have read it we are not surprised to find that he rose from the foot to the top of the ladder of learning and fame in the years that followed. "The greatest physical discoverer that ever lived," "the creator of the science of electricity"—these are some of the things that were said of him. Yet this quiet lad worked seven years in his laboratory toward one of his great discoveries before the moment came when his idea was proved to be right.

Oersted had performed his experiment in 1820. He had shown that an electric current in a moving wire could change the course of the compass needle. That showed that electricity and magnetism were connected.

Faraday pondered on this discovery. If an electric current could pull a magnetic needle, why should not a magnet start in some way an electric current? He thought it ought to be possible. But how?

Faraday worked for seven years on that problem. Then he found out its solution. One day in 1831 he thrust a bar magnet into a hollow coil of wire and got a current of electricity. "There it goes! there it goes!" he shouted, dancing round the table and rubbing his hands with glee. So excited was he at the discovery that he took the rest of the day off for a holiday, going to Astley's circus to see the performing horses.

If you want to know why Faraday's discovery of

this new way to get an electric current was a great moment in science, go to any electric power plant. You will find that the electric current which runs your tram-cars and lights your home is produced by dynamos. *Dynamis* is the Greek word for 'power.' Faraday got an electric current with a magnet and a coil of wire in 1831. In 1832 he made a little machine which he called a 'dynamo' because it furnished 'power.'

Wind, water, steam were man's sources of power at that time; and steam power was new in its use. Now came the electric current, electricity caught and flowing in a wire. And the electric current could be obtained with this machine, the dynamo.

The idea of the dynamo is simple, a moving coil of wire turning about a magnet. All that has to be done to get a current is to keep the magnet charged and the wire moving. In the simplest dynamos the wire was wound on a spindle, and the spindle turned by hand. So long as the spindle turned, the current continued. But men could not stand turning a spindle all the while.

We add a new chapter to the romance of the wheel. Do you remember how in ancient Egypt they set water turning a wheel, so that man need not stand and turn it all the while? They did the same thing with the dynamo. With the invention of the dynamo, falling water, with the tremendous force that was in it, came into its own. It could turn the wheel which could produce electricity.

'White coal' they sometimes call water power now, for the foaming water of Niagara or of any great waterfall looks white as it drops tens and hundreds of feet. As black coal in its burning in the steam engine will give power to run man's machines, so this 'white coal,' this falling water, will run the dynamo, and the dynamo will give power that need not be used at its source but can be carried hundreds of miles to do man's work for him.

Faraday's dynamo was the key that unlocked for man enormous storehouses of power. Not only did it show how to get a steady electric current, but how to turn water-power into electricity.

THE FIRST OIL-WELL IN AMERICA

Long years ago—so the story goes—before the white man came to America to live, an Indian squaw of the Seneca tribe lived near a stream which was called the 'Water of Many Colours' because of the bright colours that could be seen on its surface. This squaw loved bright colours. As a child she had spent hours sitting by the stream, watching its surface change from blue to red and green and purple and orange in the sunlight. She made blankets as did all the women of her tribe, and sometimes she boiled the thread, which she was to weave on her crude loom of crossed sticks, in dyes which she got from berries picked in the

fields. But they were never bright enough to please her.

One day, as she sat by the stream, the thought came to her that perhaps if she dipped her blanket in the rainbow water, as she dipped her threads in the pot of berry juice, she could catch some of the colours and hold them. She waited till a day when the colours were particularly bright, and floated her blanket on the surface of the stream. When she pulled it out she looked at it eagerly to see if the colours remained. Alas! the blanket was of the same dull colour as before, but it was heavy with a liquid which did not seem like water. At first she was so disappointed not to get the colours for which she longed that she paid little heed to this stuff which she was wringing out. But then she caught some of it in a jar and looked at it and tasted it and smelled it. She took some of it to the Medicine Man of the tribe to see if he knew what it was. He, too, looked at it, smelled it, tasted it, and then rubbed some of it on his hand. When she came back another day to ask him about it he told her that she had found a wonderful medicine that the Great Spirit had put in these waters for the healing of the red men.

That 'Water of Many Colours' is a Pennsylvanian stream known to-day as 'Oil Creek.' Indians followed the squaw's method of getting oil, using that which they obtained in the blankets for medicine and for rubbing on the skin. It is said that

Indian runners liked to rub their bodies with it for the tingling sensation that it gave. White men followed their example. We read that two men, working together and wringing it out of a blanket, could get nearly a barrel of medicine oil in a day.

When the early colonists occasionally struck oil as they were sinking a well, they thought it a nuisance. All their work was wasted, and there was only this stuff to show. They had to begin to dig again for water.

There came a time when some one thought of using this natural oil instead of whale oil in lamps. It was tried, and though the odour was fearful, some persistent souls kept on working with it to try to make it clear and fairly odourless. Matters had gone as far as this in the years between 1840 and 1855. Oil had begun to be of value, and it was known that there were a good many places, particularly in Pennsylvania, where there was natural oil in the ground.

In 1854 two New York lawyers, George Bissell and Jonathan Eveleth, formed a company to explore for oil. They leased the very region where the Indian squaw had dipped oil out of the stream with her blanket, the land on which the oil spring of Oil Creek was located. Then they set men digging ditches with pick and shovel; in those ditches the oil would gather, to be dipped out and put in barrels for sale.

In 1856 Bissell, in New York, saw a picture of

the derricks over a salt well which gave him a bright idea. Pennsylvania had great salt deposits, and it was the custom to drive wells in order to get the brine (salt and water mixed) from which the salt could be evaporated. The height of the derricks gave Bissell a notion of how deep they sometimes dug. If they could dig as deep as this for brine, why not drive wells to an even greater depth for oil? Wells! oil-wells! that was Bissell's idea. If there really were big pools of oil underground, would it not pay to drive deep enough to find them? Eveleth agreed to the proposition, and they engaged as superintendent of their company an oil enthusiast like themselves called Drake.

In May, 1858, Colonel Drake went to Oil Creek and began to drive a well. But as others had done before him, he struck water, so much water that the shaft of his well was flooded. Drake hit on the practical way to avoid this difficulty by forcing an iron pipe down through the water and the brine to the rock where oil would probably be found. Then the oil when it came would drive straight up through the pipe. To drive this pipe was no simple matter. Drake had to send away for an engine which was delayed in arriving. Skilled workmen could not be found. The necessary money failed to come in. The summer and autumn wore away. The following spring Drake was fortunate in getting 'Uncle' Billy Smith, a skilled old salt-well man, to drive his well for him. At this time Colonel

Drake was financing the work with his own money, as that of the New York partners had been exhausted. Uncle Billy began to work in May; by August they had got down only seventy feet, and were working through solid rock.

On August 28, 1859, as Uncle Billy and his sons were preparing to leave for the night, they noticed a liquid rising in the seventy-foot iron pipe.

"Look at this," he said to Colonel Drake.

"What does it mean?" asked the Colonel.

"That's your fortune coming," said Uncle Billy.

And so it was. By the next morning several barrels of petroleum had been drawn from the well. Colonel Drake rigged up a pump. Eight barrels of oil were pumped up that day, and still it continued to come. They had expected to have to go down five hundred or a thousand feet before they should strike oil. If it did come they thought they would be lucky to get a barrel a day. So there were few barrels ready, and no tanks. They filled everything they could lay hands on with oil, and still it came. By October they were drawing twenty barrels a day, and the well yielded oil at that or a greater rate for several years.

This was the first oil-well in America. In a few months there were hundreds. Now there are thousands upon thousands. The United States proved to be particularly rich in this liquid fuel stored by Nature thousands of years earlier in deep underground reservoirs. Another great centre for oil-wells

is Baku, in Asia Minor, where the Persian sun-worshippers built a temple long years ago, and burned petroleum on its altars. Baku is not a pleasant place to visit, for everything there tastes of oil, and, in spite of earnest efforts by the authorities, trees and plants cannot be persuaded to flourish.

It is always a wonderful event when man finds out some new treasure stored in the ground. The next great step is for man to learn how to put that treasure to some useful purpose. For a time oil was used chiefly for making kerosene for lamps. That was a gain over the dim candle lighting and the whale-oil lamps of the time. But the next great moment came when man learned to burn this oil in engines, turning it, as he had turned steam and electricity, into power.

ENGINES ON WHEELS

The first engine on wheels was a steam engine. But the steam engine was bound to be a big, heavy affair. Think of how much it has to carry about with it to keep it going! There must be coal to feed its fire; there must be plenty of water to be turned into steam in its boiler; and besides the boiler and the pistons and all the rest of the machinery there must be some one to shovel in the coal. With a coal-bin, a water-tank, and a fireman as necessary parts of its equipment, a steam

engine could never taste the joys of freedom on the road.

When oil had been discovered, and an engine had been devised that could be run by one of its light, liquid fuels, it became a simple matter to put an engine on wheels. The motor-car depended upon the invention of a new kind of engine. The small portable engine could not come until a liquid, quick-burning fuel was found. With the discovery of oil, and its use as a fuel, the motor-car was the next step.

Even after petrol was distilled it took a long time to find out how to make an engine in which the energy it gave off in burning could be turned into power. The first petrol engines were made by different inventors in France and Germany between 1860 and 1880. Gottlieb Daimler, of Germany, was probably the first to build one of the new engines into a four-wheeled vehicle for road use. He and another German, Carl Benz, both had petrol-driven motor-cars on the road between 1885 and 1890.

The development of the motor-car would probably have been much more rapid in England but for the old-fashioned laws which handicapped the experimenters at every turn. Not until the year 1896 did Parliament repeal the Red Flag Act, which compelled a man carrying a red flag to walk in front of every self-propelled vehicle, and limited the speed of such vehicles to *four miles an hour!* Nine years before this Act was repealed, an Englishman,

Edward Butler, patented a petrol-driven motor-tricycle. Benz's first internal-combustion motor, built about 1888, had three wheels and attained a speed of eight to ten miles an hour. On the Continent, the pioneers had a much freer hand to experiment and to put the results of their experiments to the test. In 1895 two clever Frenchmen, Count Albert de Dion and Charles Bouton, patented a motor-cycle, but to an English car, the Lanchester, belongs the credit of being the first to have magneto ignition. This car, an eight-horse-power vehicle, dawned upon the world in 1897, and described itself as 'silent.' Compared with its predecessors, it was not *very* noisy: but that is the most that can be said for it!

No nation upon the Continent took up the new invention with greater enthusiasm than the French, who soon organized long-distance races and had an Automobile Club of their own. Great improvements were made, notably by de Dion and Panhard; but *still*, on the other side of the Channel, nothing on wheels that was not drawn by a horse might advance at a more desperate speed than four miles an hour, and the man with the red flag *still* had to march ahead of all such dangerous contrivances.

In the year 1895, the Honourable Evelyn Ellis, an Englishman who had been in the Navy in his youth and who was keenly interested in mechanics, brought to England one of the cars made by the Panhard Company in France. It was a quaint-look-

ing object, with very large wheels, and could develop only four-horse power. But its coming marked an epoch in England. So firm was the faith of Mr Ellis in his car, he drove it to the top of one of the Malvern hills, taking as his passengers his little daughter and her French governess. Soon after that he persuaded King Edward VII to come for a drive with him, and the King was so delighted by the new experience that he at once ordered a car for himself. And a year later the Red Flag Act was repealed.

As was afterward to be the case with aviation, much progress and many improvements resulted from the big races and competitions organized by various clubs, newspapers, and enterprising people. In 1894, the *Petit Journal* arranged a trial run of motor-vehicles from Paris to Rouen. The winning car, a de Dion, attained a speed of twelve miles per hour—about two miles an hour faster than the mail-coaches of sixty years earlier! In 1902 the open international race from Paris to Vienna for the Gordon Bennett cup was won by an Englishman, Mr S. F. Edge, driving a 50 h.p. Napier.

In America an inventive person, George Selden of Rochester, N.Y., had applied for a patent for a self-propelling, horseless machine as far back as 1877, but he could persuade none of his countrymen to risk any dollars upon such an absurd scheme. The first Americans to introduce a successful internal-combustion, petrol-driven motor-engine are said to

have been two clever young mechanics, Charles and Frank Duryea, who, in 1894, carried away the first prize ever offered in their country for a horseless vehicle.

To-day, America is the greatest motor-producing and motor-using country in the world. Thanks to the genius of Henry Ford, who hit upon the happy idea of standardizing the model of his chassis, so that all parts should be interchangeable, mass-production of motor-cars is one of the most remarkable features of industrial life in the United States, and there are few citizens who do not either own a car, or hope and expect to own one before long. One in every five had attained his ambition already in 1933.

THE FIRST BALLOON FLIGHT

Man has always wanted to fly. From the Greek myth of Icarus who tried to fly over water with wax wings that melted in the sun, down through the Middle Ages, there are records of men who tried to leap out into the air on wings of their own making.

The first man who did leave the solid ground and ascend into the air did so not with the aid of wings or machinery but by the simple yet brilliant device of being floated there by the lifting power of hot air enclosed in a paper bag.

Jacques and Joseph Montgolfier were Frenchmen, living a century and a half ago in a little

village where their father was a paper-manufacturer. Before their time men desiring to fly had watched the birds. These brothers watched the clouds and the smoke that rose from a fire. They got paper bags from their father, filled them with smoke over a fire, and watched them float off into the air. "If smoke rises," they said, "perhaps hot air will rise." So they got larger and larger bags and sealed them tightly and held them as near as they could to a fire without burning them. These rose and floated high into the air.

At last they were ready to show how their air-ball or balloon worked. On June 5, 1783, they announced a public demonstration. They had built a bag some thirty feet in diameter for the occasion. People came to the little village from miles around to see what was going to happen. The huge paper bag, made stronger by being covered with cotton, was held by ropes over a low fire of straw. At first the bag was limp and had to be held above the fire. Gradually it filled out, as a child's toy balloon fills when it is blown up, until eight men were needed to hold it to the ground. Then the ropes were cut, and it sailed up into the air amid the cheers of the crowd. Watching it they thought it went a mile into the air. As the air in the bag cooled, the balloon slowly dropped. There was little wind; so it came down within a mile of the place where it started, having been off the ground for ten minutes.

"The day of flying will soon be here," said

the people, as they returned to their homes. The news of the experiment reached the King, Louis XVI, who desired to have it repeated before him. On September 19 the Montgolfiers sent up a balloon from the royal gardens at Versailles. This balloon was larger than the first and oval in shape, with an opening at the narrow end. A basket was fastened to it, and a sheep, a cock, and a duck were the unwilling passengers. The ascent was successful, the balloon sailed off for some distance, and came down in the field of a peasant, who was badly frightened by this visitor from the sky. But the animals were none the worse for their experience. That fact was most interesting to the Montgolfiers, for no one had known up to that time whether there was any air as high as a mile above the earth, or whether, if there were any, it would be fit to breathe.

What animals could survive, men dared risk. A month later a captive balloon fastened to the ground by long cables was sent up with a daring Frenchman, de Rozier, aboard. He stayed up twenty-five minutes, at a height of about one hundred feet above the ground, and came down most enthusiastic about the experience, declaring that he had greatly enjoyed the view of the country. A month later he and the Marquis d'Arlandes made the first free balloon flight. Their friends bade them farewell as if they were going to certain death. But they went up several hundred feet, were carried by the wind over Paris, and came down in safety.

This was the first time men had cut loose from the earth and voyaged in the great ocean of air.

ENGINES ON WINGS

The great moment in the history of aviation came on December 17, 1903. It happened in a barren, sandy stretch of country among the Kill Devil hills of North Carolina, to which the Wright brothers had retired to be free from interruption and observation.

On that day Orville Wright took his seat in a flying machine which he and his brother Wilbur had built and equipped with a small engine. As the machine had no wheels to give it a running start, it was set on a car which was at the top of an inclined track built on the side of a low sand hill. Wilbur gave the car a push to start it down the hill. Orville tipped the rudder to steer the machine into the air as the car shot down the track. Slowly but surely the machine left the car and soared into the air. The first flight lasted twelve seconds. They took the aeroplane back to the top of the track and gave it another start; this time it stayed up longer. A fourth flight lasted fifty-nine seconds; in that time the machine covered a distance of 852 feet.

In the early history of the world great moments stole on men unawares. They did not know that they were making history. The Wright brothers must have known exactly what it meant when their

machine stayed in the air. In that moment an age-long desire of man was fulfilled. He flew. He flew in a heavier-than-air machine driven by an engine, as a bird drives its plump little body through the air on outstretched wings.

The balloon had lifted man off the ground and carried him along through the air. In the hundred and more years between the early balloon flights and this first successful aeroplane flight men had learned how to construct balloon airships, the forerunners of our dirigibles, which they could steer and control with considerable success. But sailing through the air in a balloon basket or even motoring through it with a dirigible filled with lighter-than-air gas above you to support your engine-driven passenger car is not real flight like that of the birds. The Wright brothers knew what it was that they had succeeded in doing.

They had not stumbled on their invention by accident or without effort. Theirs was a triumph of sheer hard work and persistence, built on the patient work of men who had preceded them, and crowned with success because of certain new ideas which they had tested. They were mechanics and kept a bicycle shop where they built and repaired bicycles. They read everything that was to be read in books, magazines, and newspapers about flying machines, and there was much to read. When the Montgolfier brothers launched their first balloons no one knew anything about the upper air. There

was some doubt as to whether it was safe for a man to go up into it, whether there was any air for him to breathe. Ballooning had changed all that, and had taught men much about air currents. Sir George Cayley had written a remarkable book early in the nineteenth century in which he had given the result of his studies of the flight of birds and of his experiments with small models of what we to-day call 'gliders.' He had shown that a bird must keep moving to stay in the air, and that any machine heavier than air must do the same. He had also suggested the difficulties of balancing a flying machine, which was just the problem that the Wright brothers solved a hundred years later.

Dr Langley had built steam-driven models which flew short distances, and had launched the big machine which should have made real flights if accidents had not befallen it. Otto Lilienthal had done wonders with gliders which he tried to balance and steer by throwing his own weight from side to side, and had met his death in a daring attempt in 1896. Chanute had built successful gliders ; indeed, the Wrights modelled their first gliders on his and were in correspondence with the older man.

So with all these other men at work on the same problem, the two young bicycle makers began to build gliders. They practised with them for three years, adding various improvements. Then in 1903 they put a home-made petrol-driven engine on the wing of one of their best gliders and tried to fly

with it. That time they failed, but they persevered, making one change and then another until, on December 17, the great moment came when they stayed in the air for fifty-nine seconds.

Did they rush off and tell the world that they had mastered the secret of flight? Not at all. They went to work to improve their machine and to patent their inventions. Also, they kept their results as secret as they could until they should be ready to announce them. Reports filtered out of what these brothers were doing. But no one took much notice of them. After they had put in two more years of hard work, the world learned from its newspapers that two unknown young men in the wilds of North Carolina had made a flight of twenty miles.

The United States Government, disappointed in the results of the Langley machine into which it had put fifty thousand dollars, refused to buy the Wright patents when they were offered. Great Britain did the same. But the day of the flying machine was at hand. The United States Army wanted a flying machine if one could be built to meet their requirements. Orville Wright offered to build one for twenty-five thousand dollars, and astonished the world on the day of its official test by remaining in the air for an hour and three minutes. Wilbur Wright took a biplane to France, and won great successes there. This was in 1908, five years after that first flight. From this time on the world was aviation mad. One invention crowded on another,

one success followed another. Santos-Dumont made spectacular flights; Glenn Curtiss won a speed prize by flying at a rate of forty-seven miles an hour; Wilbur Wright, an altitude prize by climbing four hundred feet into the air; Farman, a distance prize by travelling sixty-eight miles; and Blériot crossed the English Channel. But there was hardly a machine which had not gained some secret as to balancing, steering, or placing the engine from the early machines of the Wright brothers.

"Engines on wings," we call our story, for it was the engine which made all these successes possible. In order to fly, a machine must be moving. It must therefore, except in the case of a glider, have an engine. It might still be heavier than air, provided only that it had sufficient strength and motive power. But how could a machine carry a steam engine into the air? The lightest steam engine weighed at least ten pounds for every unit of energy it produced, and must carry supplies of coal and water as well. The crude petrol engine used by the Wright brothers produced just power enough in proportion to its weight to allow itself to be lifted off the ground in this way. Five years later an engine had been made that would give one unit of power for every $5\frac{1}{2}$ pounds of its weight. Soon the ratio was brought down to one unit of power for every $1\frac{3}{4}$ pounds of weight. Then men could loop and twist and turn, and could fly to unbelievable heights and over long reaches of country, for long hours without landing.

Wonderful as are the other parts which go to make up the modern aeroplane, the engine is at the centre of it all. Without a light-weight fuel capable of running a small, powerful engine, man could never get in his aeroplane the power that would lift him off the ground and keep him in the air.

Coal turned to power in steam, electricity generated and carried in a wire, water power turned into electricity by the dynamo, liquid fuel driving a light-weight machine—these are some of the miracles accomplished by man in the last one hundred and seventy years. What other sources of power there are awaiting him, we do not know. The discovery of those resources on which he can draw will probably furnish some of the great moments of the future.

LINKING CONTINENTS BY AEROPLANE

The year 1919 was memorable in the history of flying for more reasons than one. The Australian Government offered a prize of £10,000 to the first airman who should fly from England to Australia without remaining more than 720 consecutive hours in the air, and the *Daily Mail* offered the same sum to the first airman to fly the Atlantic. Both these prizes were won in this historic year, and before it closed an American naval flying-boat, the N4, had flown from America to Lisbon in stages.

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One of the first British competitors to enter for the *Daily Mail* competition was an airman called Harry Hawker. His machine was a Sopwith, reaching a maximum speed of 118 miles per hour, and his companion in the great adventure was a naval officer, Commander Mackenzie Grieve. It was a memorable moment when those two set off from St John's, Newfoundland, in the month of May 1919. The age-long story of man's conquest over the forces of Nature had reached a totally fresh chapter, and a most exciting one. The Sopwith was fitted with wireless, and two continents waited eagerly for messages from Hawker to tell how he was faring. But hours and days went by, and no word came. A week passed. People asked each other with anxious faces what could have happened. And then, on May 25, Lloyd's signal station on the Butt of Lewis telegraphed to London :

> Danish steamer *May* passing eastward signalled following : ' Saved hands Sopwith aeroplane.' Station signalled ' Is it Hawker ? ' Steamer replied ' Yes.'

The aeroplane had been forced to descend owing to a stoppage of circulation in the water-pipe between the radiator and the water-pump. Signals of distress in the form of Verey lights were sent up by the airmen and promptly answered by the only ship in sight, which happened to be the *May*. The plucky crew of the little Danish schooner had great difficulty in rescuing Hawker and Grieve from the

rough sea, in which they were half-submerged for an hour and a half.

The attempt, though unsuccessful, marked a great moment in the science of aviation. An even greater moment was in store, when it was successfully made by another pair of dauntless Englishmen, Sir John Alcock and Sir Wilfrid Whitten Brown. These two, in a Vickers-Vimy-Rolls aeroplane, left St John's on June 14. A silence of sixteen hours followed, and then came the message 'Landed Clifden, Ireland, June 15.' The total time occupied in the flight was sixteen hours twelve minutes. The actual machine upon which it was made may be seen at the Science Museum, South Kensington. The N4 was the first machine actually to cross the Atlantic Ocean, but it did so by stages, and 'with a British-designed and British-built aeroplane, piloted by British officers, rests the honour of having made the first non-stop flight' between the new world and the old.

The prize offered by the Australian Government was won by two Scottish-Australian brothers, Ross and Keith Smith, of whom an admirer wrote, after their great flight, "they have done something which had never been accomplished by man. . . . They have pioneered an aerial route which will, in years to come, no matter how thickly the upper air may be populated with voyaging air-craft, be indissolubly linked with their names."

The machine used by the brothers was a Vickers-

Vimy-Rolls, attaining a maximum speed of one hundred miles an hour, and weighing, when the complete crew of four persons was aboard, $5\frac{1}{2}$ tons. With them Ross and Keith Smith took two plucky and skilful mechanics, Sergeant Shiers and Sergeant Bennett. They left Hounslow on November 12, 1919, and, following the line Rome—Cairo—Damascus — Delhi — Bangkok — Singapore, reached Port Darwin upon December 10.

As aviation advanced, men began to turn their thoughts to new ways in which it could be utilized, not only in commerce, but in scientific research and discovery. An overland journey to either Pole is a tedious and arduous adventure. But might it not be a very different matter if one went *by air*? In the year 1926 four Polar expeditions were launched, of which three were due to American enterprise. On May 9, Lieut.-Commander Byrd left Spitzbergen on a dash to the Pole, seven hundred miles away. Flying a Fokker, he reached and circled the Pole, returning to his base fifteen hours later. Only three days elapsed before the shadow of a flying machine moved again across the Arctic snows. The second visitor was the semi-rigid, Italian-built airship, the *Norge*, designed by Signor Nobile, and able to attain a maximum speed of seventy miles an hour. Aboard the *Norge* was the famous Norwegian explorer, Captain Roald Amundsen, who thus succeeded in his third attempt to reach the North Pole by air. Snowstorms and fogs handi-

capped the airship, but she passed from Spitzbergen to Teller, travelling a distance of 3,393 miles. The observations made by those in charge of her definitely established the important geographical fact that there is no such thing as a 'Polar Continent.' Thin ice and open water were found upon the northern summit of the globe. The exploit of the *Norge* is made all the more interesting when it is realized that Captain Amundsen was the only man who had, up to the time of his death in 1928, reached *both* Poles. At the end of 1928 Commander Byrd went by air to the South Pole, having already made a North Polar flight.

Every month that passes brings new and ever greater moments in the history of science. Sometimes the whole world is aware at once when such moments arrive, sometimes years pass before mankind realizes what has been achieved, and when, and by whom. In the sphere of aviation, man's victories have been many and glorious. Less than three months after the *Norge* flew across the North Pole an English aviator, Sir (then Mr) Alan Cobham, reached Australia in a seaplane, after a flight of ten thousand miles. On October 1, 1926, he completed the return journey, and landed on the Thames at Westminster, just opposite the Houses of Parliament, after a total journey of something like twenty-eight thousand miles in less than fourteen days of actual flying time, the greatest feat of endurance accomplished by any aviator up to that date. Sir

Alan Cobham flew a D.H. 50 J biplane, with a Siddeley-Jaguar engine, the same which he had flown previously from London to Rangoon, and London to the Cape and back. Some one asked him, at the end of his longest and most wonderful air-journey, whether he intended to give up flying. "Only," replied Sir Alan, "when I am too old to crawl into a machine!"

As the years pass aeroplanes and aeroplane engines are improved, and more and more ocean-bridging flights are made. In 1927 Colonel C. A. Lindbergh flew over the Atlantic (from New York to Paris) in thirty-three and a half hours—the first solo crossing. Three years later C. W. A. Scott reduced the time for the air journey from England to Australia to less than ten days. In 1934 the same airman, with T. Campbell Black as his companion, covered the 10,000 miles to the Southern Continent in two days, twenty-three hours. Wiley Post, a famous American flyer (he was killed two years later), in 1933 travelled round the world (15,596 miles) in a few hours less than eight days. Each year thus brings its new achievement, and rapidly the aeroplane is breaking down all the barriers of distance which separate the peoples of the earth.

THE WORLD MADE ONE

The First Telegraph : The Atlantic Cable : Making Iron Talk—The Telephone : Storing Human Speech—The Phonograph : Round the World by Wireless

IN the ancient myths which tell of the discovery of fire, it is almost always explained that the gods objected to man's having fire because when he could create fire he would become as one of them. When the U.S. Congress was discussing in 1842 whether it was willing to spend money to test Morse's newly invented telegraph by building a line between Washington and Baltimore, we find a like idea, that if man could bridge space in that way he would have gone beyond ordinary human powers and become superhuman. The chairman of the committee which was urging the building of the line said frankly that it was so startling as to seem almost irreverent for man to annihilate space. Only to God had it been possible to be everywhere at one and the same time. Years before Edmund Burke had exclaimed in the House of Commons that even the gods might not annihilate time and space. Yet here was this amazing invention by which it was claimed that a man might sit at an instrument in one place and send messages over a wire to a man twenty, thirty, forty, one hundred

or even more miles away. If such a thing could be done, it would lift man above being a mere man into something greater. For practical purposes he would be able to do business in two places at the same time.

Congress did decide to install the telegraph, as we shall see in the next story. Its members little thought that within fifteen years after that first line was installed the President of the United States and the Queen of England would be exchanging compliments over the Atlantic cable; that within thirty-five years men would be actually talking over wires; and that eighty years later men would be talking across space without wires. There are no more thrilling stories than those which tell how in the last hundred years man has achieved the conquest of space.

THE FIRST TELEGRAPH

A great moment in the history of human progress came in July 1837, when Wheatstone's telegraph was tested, and its value was proved, for the first time. The idea of transmitting words by electricity did not originate with Charles Wheatstone, though he was the pioneer of electric telegraphy in Europe. Toward the end of the eighteenth century a Scottish doctor, Morison by name, had suggested that the thing *might* be done, and early in the nineteenth a Londoner, Mr Ronalds, had proved

that it *could*. Nothing, however, came of either the suggestion or the experiment. Six or seven years passed before the electric telegraph attracted general attention, and was carried beyond the experimental stage. But the real 'father' of the telegraph in England was not Wheatstone but an officer in the Madras Army, William Fothergill Cooke by name. Cooke happened to be home on leave in the year 1836. In the great lecture hall of Heidelberg University he saw a toy, or model, telegraph, rigged up for demonstration purposes, which set him thinking hard. If a couple of magnetic needles could be made to vibrate by turning on and shutting off an electric current, why should not those same vibrations be made to serve some useful purpose?

When Cooke reached England he got into touch with one of the leading practical scientists of the day, Charles Wheatstone, professor of experimental physics at King's College, London. Wheatstone had begun his career as a maker of musical instruments, but he turned his attention to science betimes, and contributed important papers on light and optics to the transactions of the Royal Society. In 1837 he and Cooke took out a patent for "improvements in giving signals and sounding alarums by means of electric currents transmitted through metallic circuits." The first public trial of the Wheatstone-Cooke telegraph took place on July 25, 1837, some five months before Samuel Morse,

the American inventor, gave *his* first demonstration in the United States. We shall return to Morse very soon. On that momentous summer day in London, eighty-nine years ago, Cooke was stationed at Camden Town and Wheatstone at Euston. Among those present were two famous engineers, George Stephenson, the creator of the *Rocket*, and Isambard Brunel, the bridge-builder. "Never," writes Wheatstone, "did I feel such a tumultuous sensation!" We can sympathize with his excitement, for he realized that this new method of employing electricity was fated to alter the whole colour and form of existence on this planet. The demonstration was completely successful, and many progressive people were soon converted to a firm belief in the enormous possibilities of the invention. The first public telegraph in England was that between Paddington and Slough, established in 1844. The wires were hung between posts along the line of the Great Western Railway. For the first time in military history, the telegraph was used during the Crimean War—1854–56. Wheatstone's instrument recorded by means of a needle—at first there were *five* needles: another, and, as events proved, a better method, based upon the electro-magnet, was invented by Samuel Morse. The American pioneer was the son of a clergyman in the State of Massachusetts, and received his education at the Phillips Academy, Andover, and Yale College. It was at Yale, when studying under

Professor Silliman, that he first learned of the new marvel, electricity.

But painting, not science, was Morse's special interest. In college he painted small pictures of his friends, which he sold to them for five dollars each. After leaving college he studied under one of the best-known painters of the day, and accompanied him to England for further study. There he won unusual notice for so young a man, receiving a gold medal for work in sculpture and having his paintings hung with those of England's best artists. His money gave out, and he went home. While he found instant recognition as a painter it was extremely hard, in spite of his popularity, to earn a living by his art. A year after his return we find him and his brother inventing an improvement for a fire-engine pump in an attempt to get a little extra money. In 1829 he went abroad again to spend three years working in the art centres of Europe.

It was on the voyage home in 1832 that his interest turned to electricity and the telegraph. One of his fellow-passengers was a Boston physician, Dr Charles T. Jackson, who had seen the famous French scientist, Ampère, perform brilliant experiments with electrical apparatus, and was bringing home an electro-magnet which he exhibited in the ship's cabin. Morse was interested because of his early studies at Yale, and made many inquiries. Learning that electricity, induced by an electro-

magnet, could be made to pass over wires for any distance, and that its speed in such travel was practically instantaneous, he made the remark, "If that is so, I see no reason why intelligence should not be transmitted instantaneously by electricity." Or, in the simpler language of our day, "Why should not news be sent?"

It is one thing to have an idea; another, to carry it out through the long processes and difficulties of invention. Would it be possible for Morse to arrange an electrical device containing an electric magnet, by means of which signals and messages could be sent long distances over a wire? To us the idea is so familiar that it seems obvious. One hundred years ago it was startling and revolutionary.

For all the rest of the long voyage Morse worked on the idea, filling his notebook with sketches of apparatus and schemes for an alphabet of dots, lines, and spaces. When he landed he remarked to the captain of the boat, "Well, Captain, should you hear one of these days of the telegraph as the wonder of the world, remember the discovery was made on board the good ship *Sully*."

The wonder is that Morse had the enthusiasm and persistence to push through to success. He had very little money, hardly enough from his art work even to live. No one knew much about electricity; so it was hard to get the needed materials. A blacksmith's was the nearest approach to an elec-

trical shop, for here one might get iron to bend into a magnet and wind with wire. He himself had little scientific knowledge, and less experience with such apparatus. He rented a tiny studio in a New York office building where he ate (when he had money to buy food), cooking his own meals there, and sleeping and working in the midst of a muddle of artists' materials and electrical tools.

But he was possessed with his idea. The fact on which he worked was the discovery made by Hans Oersted a dozen years before. When an electric current is sent through a coil wound about a bar of soft iron, the iron becomes a magnet. Oersted proved that, you remember, by showing that a compass needle was pulled by that magnet. When the current is shut off the iron ceases to be a magnet. Somehow, by Morse's plan, a machine must be made by which a person at one end of a wire could start a current and then break it, start it and break it, in a way that would give signals to a person sitting at the other end of the wire. That was what he was trying to accomplish. The difficulties in the way of carrying it out were tremendous, particularly to one who had neither money nor the right kind of supplies.

Morse toiled for three years, and finally had a sending instrument which worked fairly well. When he was asked later why he did not make a second machine at the same time to send an answer back, he replied that he had not the money to

construct it. He did not borrow, he went on to explain, because he had always had a principle against going into debt, and he preferred delay because he could not be sure that he would ever be able to pay back such a loan. To-day the materials for such an instrument would probably cost about twenty shillings.

Five years after Morse had begun his work there came the fortunate meeting with Alfred Vail, a young man whose father, Judge Stephen Vail, had built in his own iron works in New Jersey the engines for the first steamship to cross the Atlantic. Vail went to a private exhibition of the telegraph, and became very interested in its possibilities. He joined Morse as a working partner and helped him to improve the instruments and to work out the now familiar Morse code of dots and dashes used in signalling. Judge Vail gave his son two thousand dollars for the work, and allowed the use of his foundry.

In that same year, 1837, Congress became roused to interest by similar work being done abroad, especially by Sir Charles Wheatstone and William Fothergill Cooke. A circular was sent out by the Secretary of the Treasury asking for reports on such work as was being done in private laboratories in America. Morse sent at once a full description of his instrument.

Meanwhile Judge Vail was being laughed at by his friends for having put money into this wild

scheme. He began to become a little doubtful himself as the weeks dragged on and he saw no results. On January 6, 1838, a foundry boy was sent to Mr Vail's house to ask the judge to step over to his son's shop in the foundry. There he was asked to write the message he wished to have sent and received on the new telegraph. He wrote the message, "A patient waiter is no loser," and handed it to his son. His son clicked it off on his instrument. Shortly Morse, who was at the other end of the line, reported its receipt. The test had worked, the message was accurately received, and the judge was most enthusiastic. The telegraph had been invented.

Six years later a Bill was before the Congress of the United States to build a forty-mile telegraph line as a Government experiment. Morse had been through all sorts of difficulties in those six years; it had seemed impossible to arouse any interest in the invention. The Bill finally passed the House by eight votes and was referred to the Senate. There it seemed doomed; there were hundreds of Bills ahead of it.

On the last night of the Session Morse sat in the gallery waiting for the vote. A Senator came to him and said: "There is no use in your staying here. The Senate is not in sympathy with your project. I advise you to give it up, return home, and think no more about it."

The inventor went back to his hotel utterly discouraged. His last chance seemed gone. When he paid his bill after breakfast the next morning, and had bought a ticket to New York, he had just thirty-seven cents left in his pocket.

But before leaving the hotel a visitor called to see him. It was Miss Annie G. Ellsworth, the daughter of his friend, the Commissioner of Patents.

"I have come to congratulate you," she said.

"Indeed, for what?" inquired the downcast inventor.

"On the passage of your Bill."

Morse assured her that she must be mistaken. He had stayed late, and there was no hope for it. She told him that her father had stayed until the end, heard the measure carried through without debate, and then had seen the President put his name to the Bill.

"You shall send the first message over that telegraph line when it is opened," exclaimed Morse in delight; and so it happened.

On May 24, 1844, the line was to be opened. Miss Ellsworth handed to Morse, who was sitting at a sending instrument in the Supreme Court Room of the Capitol Building, a paper on which was written, "What God hath wrought." Morse ticked the words over the wires to Baltimore, where Vail received them and in a few moments ticked them back.

The telegraph had come into its own.

THE ATLANTIC CABLE

On August 5, 1858, President Buchanan received the following message:

To the President of the United States,
Washington, D.C.

DEAR SIR,

The Atlantic Telegraph cable on board the U.S. steam frigate *Niagara* and her British Majesty's *Agamemnon* was joined in mid-ocean, July 29th, and has been successfully laid; and as soon as the two ends are connected with the land lines, Queen Victoria will send a message to you, and the cable will be kept free until your reply has been transmitted.

With great respect,

I remain

Your ob'd't serv't,

CYRUS W. FIELD

In this brief letter is told the story of one of the great moments in world communication, when England and the United States were joined by slender wires stretched under two thousand miles of ocean, and Queen Victoria and President Buchanan could exchange within a few brief minutes messages of mutual congratulation.

That moment had not been reached without tremendous effort amid heart-breaking disappointments. Reading the story of some of these early undertakings, like the telegraph, the telephone, and the submarine cable, one stands aghast at the series

of trials and misfortunes through which these pioneers worked. Time and again their hopes were wrecked by accident or poverty or some mischance due to facts unknown to anyone until they had been learned by costly experience. Yet the faith in their inventions carried them on until they were borne on the crest of the wave to success.

As the cable is simply an under-water telegraph system, it is natural that Morse should have built one of the first cable lines. He laid it under New York Harbour in 1842, while he was still waiting for Congress to become interested in his invention. Other lines were laid abroad, under the English Channel, and between England and Ireland. In 1852 Cyrus W. Field, a young merchant of New York, became interested in the idea of laying a cable which should connect the Old World with the New. From the moment when the idea first came to him until the deed was done, this was his ruling passion. To it he devoted every ounce of his strength and enthusiasm.

Both the British and the American Governments responded cordially to the idea of a submarine telegraph. Naval vessels made soundings of the depths of the ocean for the proposed routes. A company was organized to finance the project, with Cyrus Field putting in one-fourth of the money which was thought to be needed. It seemed as if the idea was on its way to quick fulfilment. But these enthusiasts reckoned without the difficulties.

First the cable must be made. It was decided to build two thousand five hundred miles of cable, although the distance over the proposed route between Ireland and Newfoundland was a little less than two thousand miles. The cable was to carry seven copper wires, these being insulated with gutta-percha, wound with tarred hemp, and protected by a heavy casing of iron wires. To lay the cable England offered the *Agamemnon* and the United States the *Niagara*, warships large enough to carry this bulky load and the machinery with which it should be paid out into the water. Experience proved that this machinery was one of the most important and difficult problems of the task.

In 1857 the vessels set out from the Irish coast. When four hundred miles had been safely laid the cable broke. All the section that had gone overboard was hopelessly lost. Half a million dollars had been sunk in the enterprise. There was nothing to do but give up for the time.

In June 1858 another attempt was made. This time the two vessels were to go to mid-ocean, each with half of the cable coiled in its hold. There they were to splice the two parts and begin to lay them in opposite directions. On the way out there was a terrible storm which the overloaded vessels barely survived. Arrived at mid-ocean, they spliced the cable and began to pay it out. With three miles laid the cable broke. They returned and spliced it again. This time they got fifty miles apart and

it broke. Again they returned and made another splice. They went very cautiously this time, and got two hundred miles apart. Suddenly and without warning the cable broke and disappeared into the sea. The expedition must be given up.

Now surely the attempt would be abandoned. But no! in July they were at it again with better machinery. This time the vessels had been separated only three hours after the splicing was done when a very large whale appeared, approaching the *Agamemnon* with great speed. It seemed as if it were making direct for the cable, but fortunately it merely grazed it and passed on. The *Niagara* meanwhile passed alarmingly near enormous icebergs, but steered by them without the cable being hit. On August 5 Mr Field could report to President Buchanan that both ends of the cable had been safely landed. The Queen and the President exchanged greetings, and the great achievement was regarded as completed.

Then, with the cable a little less than a month old, after 732 despatches had been sent, messages ceased. The electricians had not fully understood the needs of such a cable. Too much pressure had been put on it in the effort to send messages so great a distance, and it was ruined. Think of the disappointment to Cyrus Field and to the men who had put their money in again and again! Years of effort, vast sums of money spent, two governments involved, one month of messages—and then only a

useless collection of wires running for two thousand miles under water but silent for ever!

Happily the month during which the cable had operated had shown its value. In one despatch the British War Office had countermanded the departure of two regiments which were about to leave Canada for England and had saved by that single message £50,000. When a difficulty came up a little later between England and America we find the *Times* speaking of the cable as a peacemaker, and saying, "We nearly went to war with America over the *Trent* affair because we had no telegraph across the Atlantic." In 1859 the British Government appointed engineers to consider whether a cable could be laid and kept working. They reported in 1863 that it could. Meanwhile the Civil War had broken out in America.

In 1865 Cyrus Field organized another company, chiefly with English money, and chartered the *Great Eastern*, a vessel large enough to carry the whole cable at once. This time they proceeded with the most anxious care, and got two-thirds of the way across the Atlantic when the ship's machinery broke under the tremendous strain and the cable snapped and was lost. Three times they grappled for it in eleven thousand feet of water and three times they brought it to the surface, only to lose it overboard again. The *Great Eastern* went back to home waters, but did Field give up? Not for a day. A new company was formed, new money

was obtained, and in July 1866 a second cable was successfully laid in the short period of two weeks. Then the *Great Eastern* was put to work to reclaim the cable lost the year before. Again and again this cable was located, lifted to near the surface of the water on grappling hooks, and lost. Twenty-nine times that ship's crew caught it, lifted it, and lost it again. The thirtieth time they brought it to the surface and carried it to the station at Newfoundland. So that summer's work resulted in two cables uniting the British Isles and the American continent, both incomparably better in quality than the original one that gave only a month's service.

Since that summer the two worlds have been in constant communication under the broad ocean that divides them.

MAKING IRON TALK—THE TELEPHONE

"If I can make a deaf mute talk, I can make iron talk." In these words, spoken by Alexander Graham Bell, the telephone was born.

Bell could make deaf mutes talk. He was doing it at a school which he had started in Boston. His father, a distinguished Scotsman, had invented a system which he called 'visible speech.' He showed deaf mutes who had never heard a sound in what positions the mouth, lips, throat, and tongue were held to make sounds. By imitating people who spoke, they learned to speak. Young Alexander had

known about these things from childhood. When he was a boy he and his brother had invented a device which said *Ma-ma* as well as some of our modern dolls say it. He knew as hardly any other man in the world knew just how sounds were made, how they were carried in the air, and how they could be heard.

Of course, such a man was exactly the one to invent the telephone. The marvel is that so famous a teacher should have become interested in the idea and have gained the electrical knowledge to make such a machine.

Bell went up to London as a young man and there met Sir Charles Wheatstone. He became tremendously interested in the telegraph and also in some German experiments in which a tuning fork was being set in motion by an electric current and made to give out sounds without being struck. If a tuning fork could be made to give out sounds in this way, why should a telegraph wire signal only by long clicks and short? Why should it not be possible to have a musical telegraph in which sounds were carried over the wire? Bell pictured a musical telegraph with as many notes as the keys of a piano. Several messages could then be sent over the wire at the same time by 'playing' different tunes on the keys.

After he came to Boston and started his famous school there, he was at first too busy to think of his plan for a musical telegraph; but later, with an

inventor friend who was the father of one of his pupils, he returned to it. Finally, with the backing of this man and of the father of another pupil, he gave up the school to devote all his time to this invention.

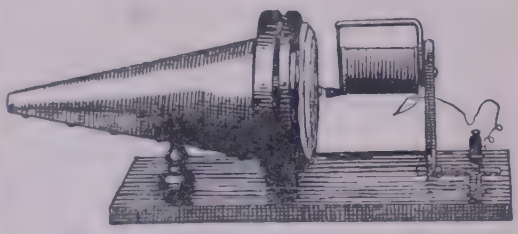
As he worked on it, the larger idea came to him, "If I can make a deaf mute talk, I can make iron talk." No longer was he satisfied with the idea of sending only the notes of the scale over a telegraph wire. He wanted to be able to talk into a wire, so that some one at the other end of the wire should hear the words as he had spoken them.

To us, to whom the telephone is so familiar, the idea seems simple and reasonable. To Bell's two backers, who were paying all his bills, and to others with whom he talked, it seemed crazy. A musical telegraph they had begun to believe in, but talking over a wire was beyond reason. So Bell had to agree to devote half his day to the musical telegraph, saving only half for his new idea.

The steps by which he came to his success are too many to record here. He worked in the attic of an electrical shop in Boston, with an apprentice assistant called Watson. One hot June day, when they were trying one of their endless tests, a faint sound came over the wire. Bell rushed into the room where Watson was trying to send signals. "What did you do then?" he cried. "Don't change anything. Let me see." For forty weeks Bell worked on the discovery made on that June

day. Then on March 10, 1876, Watson, standing in the basement at one end of a telephone wire, heard Bell, who was in the attic, say over the wire, "Mr Watson, please come here. I want you." That was the first telephone message ever sent.

The first telephone really did seem to make iron talk. There was a mouthpiece with a small disc of soft iron set into it. When words were spoken into it they set sound waves moving in the air, which set the iron disc moving or vibrating. The movements in the disc varied the electric current in the wire which led to the receiving instrument at the other end. Here there was another iron disc. The electric current made this second iron disc vibrate exactly as the first one had done. By vibrating in this way the second iron disc said into the air the words spoken at the other end of the wire. It was as if the first iron disc listened to the words; they were changed into electric current and travelled along the wire; the second iron disc caught them and changed them back into sound, into the same words. That is practically the same system as that on which our telephones work to-day.



BELL'S ADJUSTABLE TELEPHONE
Alexander Graham Bell said he would "make iron talk," and he did.

The telephone had been invented, but no one was particularly interested. The great Centennial

Exhibition for the celebration of the one hundredth anniversary of the signing of the Declaration of Independence was then being opened in Philadelphia. Mr Hubbard, one of the two men who had backed Alexander Bell through all the years of work on the telephone, got a small table in a remote corner of the building behind the stairway for the exhibition of the new machine. It was there for six weeks and no one paid any attention to it. Finally Bell went to Philadelphia himself and sat at the table behind it. Sometimes a passer-by stopped to look at it and allowed him to show how it worked. They were interested in it as a curious scientific toy. But of what use could it ever be? Suppose speech could be sent over a wire, who cared?

At last the judges came to inspect this machine, as they were inspecting every exhibit in the building. It was seven o'clock in the evening. They were tired, hot, and hungry. One took up the telephone receiver, looked at it, and put it down without even lifting it to his ear. The group was passing by when suddenly their attention was caught.

Dom Pedro, the young Emperor of Brazil, the most picturesque figure at the Exhibition, came up accompanied by the Empress Theresa and attended by a retinue of gaily attired countrymen. Seeing the young inventor he rushed up to him and greeted him with enthusiasm. He had visited his

school for deaf mutes in Boston years before and been greatly interested. He inquired what Professor Bell was doing here. Bell showed him his machine and gave him one of the receivers. Dom Pedro stood holding it at his ear while the group of judges and attendants looked on. Bell, at a little distance, spoke low into the other end of the wire.

"My God, it talks!" said Dom Pedro.

The great moment had come. The judges, looking on, returned to hear this toy for themselves. They stayed till ten o'clock that night 'listening-in' as one after another spoke into it. The machine which has been said to be "the most valuable single patent ever issued" was pulled out from its dark corner behind the stairs and placed in the judge's pavilion where the public could see and wonder at it. The telephone had come into its own.

Bell had received his patent on his twenty-ninth birthday. On March 10, 1876, he had stood in the attic of the Boston shop and spoken to Watson in the cellar. Watson had dropped the receiver and rushed joyfully up three flights of stairs to say, "I can hear you. I can hear the *words*!" In January 1915 Alexander Graham Bell, full of years and honour, sat in New York at an instrument which was an exact reproduction of his first machine. He was opening the first transcontinental telephone line. Again, as on that first memorable day, he said, "Mr Watson, please come here. I

want you." And Watson, who was sitting at the other end of the line in San Francisco, replied, "It would take me a week now."

STORING HUMAN SPEECH—THE PHONOGRAPH

One summer day in 1877 the young inventor, Thomas Edison, was at work in his laboratory when one of his assistants, John Kruesi, came and put on his table a model of a little machine which Edison had told him to make. It was Edison's custom to draw on paper a design of a machine he wanted made, write instructions as to the way to put it together and the materials to be used, put down the amount of money he would pay for it, and hand the paper to one of his men. Kruesi, one of his best model-makers, had received such a paper a few days before, with instructions and a price limit of eighteen dollars. Now the machine was done, and he brought it to Edison.

Edison looked at it, turned its handle, took a sheet of tinfoil and fastened it round a revolving cylinder which was turned by the handle. By this time not only Kruesi was watching, but other men in the laboratory had gathered round, for they had heard that Edison had said that this queer model was to "record talking," and they wanted to see if it would work. Edison adjusted the mouthpiece, which was like that of a telephone, and began to

turn the cylinder with the handle, shouting into the mouthpiece as he did so :

Mary had a little lamb,
Its fleece was white as snow,
And everywhere that Mary went
The lamb was sure to go.

The men stood round laughing and joking at his recitation. Edison turned the cylinder back, re-adjusted some hidden machinery, and then turned the cylinder round again. As he turned the handle, out from the machine came a thin, small voice :

Mary had a little lamb,
Its fleece was white as snow,
And everywhere that Mary went
The lamb was sure to go.

" *Mein Gott in Himmel !* " exclaimed John Kruesi, the faithful instrument-maker who had just built the machine which was giving this performance. And Edison himself confesses to equal surprise.

" I never was so taken aback in my life," says Edison of that moment. He had expected to catch a word or two imperfectly. But here were the words given back clearly and exactly.

Edison had hit on the idea of a machine that would talk while he was working on an improvement for the telegraph. He was trying to make a device that would record more rapidly than any operator could receive them the messages as they came in over the wire. To do this he had made a

revolving disc of paper on which the dots and dashes were to be recorded and had set a metal point like a pen writing on it. One day, as the disc was turning rapidly, a sound was given out. Edison reflected upon what could have caused that sound, and made up his mind that a talking machine could be made. This model was the result.

When the men in the laboratory realized what Edison had accomplished they joined hands and sang and danced round him. Then they began putting on new strips of tinfoil, talking, shouting, singing into them, and then turning the crank and hearing it repeat what they had said or sung. None of them went home that night. They stayed till dawn, marvelling at the wonderful, simple toy.

The next morning Edison took his little phonograph under his arm and went over to the office of the *Scientific American* in New York. Here he did the same thing, putting his model on the desk of the editor, solemnly reciting

Mary had a little lamb—

and then turning the crank, while the machine said it back to him. Work ceased in the big editorial room. Every one crowded round the machine. The story of it spread through the building, and so many persons rushed in to see it demonstrated that the editor was afraid the floor of the room would give way. The newspapers of the next morning were filled with accounts of this machine that would

record and then reproduce the human voice, and the fame of it spread with astonishing speed over Europe and America. No invention ever leaped into public notice more quickly than did the phonograph.

What was it about this machine that gave it such an appeal? Why was it a great moment in science when it was invented? Once more man had won a notable victory over time and space. A man might speak or sing into it in Paris or New York. The machine would take the speech or song as the camera takes the record of an event by a flash of light. That speech or song could then be heard all over the world in exactly the tones in which it was given. Not only that! it could be heard ten, twenty, one hundred years later as well as on the day after the record was made. Through such phonograph records our children's children will hear the voices of men and women gone from the earth before they were born. The gramophone, the popular successor of the phonograph, has many interesting and practical uses in everyday business life and in entertainment. But its real place is in its wider service in giving man this victory over time and space.

ROUND THE WORLD BY WIRELESS

To no one man can be given the credit for discovering the facts and thinking out the theories which led to the modern miracle of talking across

space without wires. Perhaps Faraday began it with his wonderful studies of the 'fields of force' about a magnet and of the general principles of electricity. "Action at a distance" was his striking description of some of the effects which he observed. Maxwell a few years later announced the theory that electro-magnetic waves travelled through the ether of space at the same rate and in the same manner that light waves did. Heinrich Hertz a few years later produced and detected those waves. Sir William Crookes wrote in 1892: "Here is unfolded to us a new and astonishing world. . . . Rays of light will not pierce through a wall, nor, as we know only too well, through a London fog. But the electrical vibrations . . . will easily pierce such mediums. . . . Here, then, is revealed the bewildering possibility of telegraphy without wires, posts, cables, or any of our present appliances."

Guglielmo Marconi, son of an Italian father and an Irish mother, was twenty-one years old when he began to try to use these electric waves for the practical purpose of sending messages across space. In 1895 he made experiments at his father's villa on the outskirts of Bologna in Italy. At first he sent his message over a space of only a few yards, and then from room to room. Next he tried longer distances in the garden. In 1896 he went to England and took out his first patent. He used a Morse key for sending and an equally familair 'eye' or 'detector' for receiving. In one sense there was

nothing new in his apparatus so far as its single pieces went. The novelty came in the way he put them together and the result he accomplished with them.

Marconi's first English experiments were made in London between Government buildings. The British Post Office officials showed a cordial interest in his invention and gave him every facility for carrying out tests. Their wildest dream, as one of them later remarked, was that such signals might come through for half a mile. In 1897 Marconi sent messages under their observation over a space of four miles on Salisbury Plain. In 1898 a Dublin newspaper got news of boat races at Kingstown from a ship which followed the boats and sent reports ashore. Messages were successfully sent across the Channel, and on January 19, 1903, a message of greeting was sent from Theodore Roosevelt, then President of the United States, to the King. This was only forty-five years after the notable interchange between President Buchanan and Queen Victoria over the Atlantic cable. But while that exchange of greetings had come only after two thousand miles of heavy cable had been laboriously laid under the sea, this message covered a greater distance from Wellfleet on Cape Cod to Poldhu, in Cornwall, without an intervening wire. To-day a message can be sent right round the world in a few seconds.

By wireless the world is made one. The peoples

of the earth are bound together by an invisible bond over which speech can be freely carried. The telephone is now linked to the wireless systems of the world, and the oceans present no barrier to those who wish to talk with their friends in distant countries. An ocean cable can be cut. But the invisible ether through which electric waves travel is subject to no hazards—and, further, knows no national boundaries. A whole country, half the world, can be the audience of a single speech. News can be given a world-wide distribution in a few moments. Not only this, but by the most recent development of wireless, television, entertainment and news can be conveyed to the eye as well as the ear. The aeroplane circles the globe more rapidly than man has ever before travelled. The wireless is as swift as human speech. Through it man has won his greatest victory over time and space. By its means the world is made one.

A TIME-TABLE OF GREAT MOMENTS IN SCIENCE

A TIME-TABLE OF GREAT MOMENTS IN SCIENCE[1]

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[1] This time-table is too brief to be either exhaustive or entirely accurate, but is intended to serve as a guide or index for readers of the book.

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